AFGL-TR-78-0053
ENVIRONMENTAL RESEARCH PAPERS, NO. 626

Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4

J. E. A. SELBY
F. X. KNEIZYS
J. H. CHETWYND, JR.
R. A. McCLATCHEY

28 February 1978

OPTICAL PHYSICS DIVISION   PROJECT 7670
AIR FORCE GEOPHYSICS LABORATORY
HANSCOM AFB, MASSACHUSETTS 01731

AIR FORCE SYSTEMS COMMAND, USAF

This report has been reviewed by the ESD Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

John Howard

Chief Scientist

Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.

9 Environmental research papers

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER
AFGL-TR-78-0053, AFGL-ERP-626

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

6

4. TITLE (and Subtitle)
ATMOSPHERIC TRANSMITTANCE/RADIANCE: COMPUTER CODE LOWTRAN 4.

5. TYPE OF REPORT & PERIOD COVERED
Scientific. Interim.

6. PERFORMING ORG. REPORT NUMBER
ERP No. 626

10

7. AUTHOR(s)
J. E. A. Selby*
F. X. Kneizys
J. H. Chetwynd, Jr.
R. A. McClatchey

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Air Force Geophysics Laboratory (OPI)
Hanscom AFB,
Massachusetts 01731

16

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62101F
76700905

17 401

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Geophysics Laboratory (OPI)
Hanscom AFB,
Massachusetts 01731

11

12. REPORT DATE
28 Feb [redacted] 78

13. NUMBER OF PAGES
100

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

12 102 p

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Present address Grumman Aerospace Corporation

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Atmospheric transmittance
Atmospheric radiance
Infrared
Visible
Atmospheric optics
Radiative transfer
Attenuation
micrometers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a computer code for predicting atmospheric transmittance and the thermal radiation emitted by the atmosphere and earth in the wavelength range from 0.25 to 28.5 μm at a spectral resolution of 20 cm^{-1}. The program is based on the LOWTRAN 3B (1976) computer code and includes the same data package. The effect of aerosol radiance and nitric acid (HNO_3) transmittance and radiance is included. The computer code also contains six standard (geographical and seasonal) atmospheric models and four standard aerosol models with an option to replace either with non-standard or

next page

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

411 578

20. (Cont)

measured values. The program can be run in one of two modes, namely, to compute only atmospheric transmittance (as LOWTRAN 3B) or radiance and atmospheric transmittance for any given path geometry.

Contents

Illustrations

Illustrations

Tables

Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 4

1. INTRODUCTION

This report describes the development of a Fortran computer code LOWTRAN 4 designed to calculate atmospheric radiance and/or transmittance for a given atmospheric path at moderate spectral resolution. The present code is based on the current LOWTRAN atmospheric transmittance code, LOWTRAN 3B[1] (and its predecessors LOWTRAN 3,[2] LOWTRAN 2,[3] LOWTRAN 1[4]). All the capabilities of the LOWTRAN transmittance codes have been preserved in the conversion of the computer code to atmospheric radiance calculations. The LOWTRAN 4 program will perform either atmospheric transmittance or radiance calculations. The mode of the calculation is determined by a single input control parameter.

(Received for publication 27 February 1978)

1. Selby J. E. A., Shettle, E. P., and McClatchey, R. A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B AFGL-TR-76-0258.
2. Selby, J. E. A., and McClatchey, R. A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255.
3. Selby, J. E. A., and McClatchey, R. A. (1972) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-TR-72-0745.
4. Manley, O. P., Smith, H. J. P., Treve, Y. M., Carpenter, J. W., Degges, T. C., and Doan, L. R. (1971) OPTIR II, AFCRL-71-0528 (Vol. 2 & 3); (1973) OPTIR III, AFCRL-TR-73-0217 and 0491; and (1974) OPTIR IIIB, AFCRL-TR-74-0319.

Continuity with the LOWTRAN 3B transmittance code has been retained. Changes in the program required for radiance calculations have been minimized. Only two new subroutines have been added to the program. Although a new card sequencing has been established in the LOWTRAN 4 program, a comparison with the previous LOWTRAN 3B code has been provided (see Appendix A) to facilitate user conversion of this program to the radiance mode.

In this report, we will describe the changes made in the transmittance code. These include a discussion of the method used in the calculation of atmospheric radiance, the addition of HNO_3 as an atmospheric absorber, and the modification of the empirical transmittance functions for small absorber amounts. In addition, instructions for using LOWTRAN 4 are given in Section 6. A listing of the computer code and data is given in Appendix A (note data is the same as LOWTRAN 3B). A flow chart of the program is provided in Appendix B, and a definition of symbols in Appendix C. Sample output from the program is provided in Section 7. Examples of atmospheric radiance calculations from LOWTRAN 4 are presented in Section 8. Comparison with measurements are given in Section 9. Some comments on the program use are discussed in Section 10.

The latest errata sheet (September 1977) to the LOWTRAN 3B (1976) code has been reprinted in Appendix D. Users of the LOWTRAN 3B program should verify that the corrections listed in Appendix D have been made in their present codes and in the conversion of their codes to the radiance mode, as described in this report.

Users of the current LOWTRAN 3B transmittance code will find this report sufficient in itself for performing atmospheric radiance/transmittance calculations. For those unfamiliar with the LOWTRAN band model type calculations, more complete information is provided in the previous LOWTRAN[1-4] reports, as well as the Optical Properties of the Atmosphere Report.[5]

The computer code has been tested for atmospheric radiance calculations for various atmospheric paths. However, no attempt has been made at this time to optimize either the computer code or the execution time. If any discrepancies are encountered or problems occur in the use of the code, please notify F.X. Kneizys, AFGL/OPI, Hanscom AFB, MA 01731.

The LOWTRAN 4 card deck will be made available from the National Climatic Center, Federal Building, Asheville, NC 28801 for a charge of $20.00. (Please address requests to Mr. R. Davis.)

5. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S. (1972) Optical Properties of the Atmosphere (Third Edition) AFCRL-72-0497.

2. ATMOSPHERIC RADIANCE

The LOWTRAN 3B transmittance program has been modified to calculate atmospheric and earth radiance. A numerical evaluation of the integral form of the equation of radiative transfer has been added to the program. The emission from aerosols and the treatment of aerosol and molecular scattering were considered only in the zeroth order. Additional contributions to atmospheric emission from radiation scattered one or more times has been neglected. Local thermodynamic equilibrium was assumed in the atmosphere.

The average atmospheric radiance (over a 20-cm^{-1} interval) at the frequency, $\bar{\nu}$, along a given line-of-sight in terms of the LOWTRAN transmittance parameters is given by

$$I(\bar{\nu}) = \int_{\bar{\tau}_a^b}^{1} d\bar{\tau}_a \; B(\bar{\nu}, T)\bar{\tau}_s + B(\bar{\nu}, T_b)\bar{\tau}_t^b \qquad (1)$$

where the integral represents the atmospheric contribution and the second term is the contribution of the boundary, (for example, the surface of the earth or a cloud top) and

$\bar{\tau}_a$	=	average transmittance due to absorption,
$\bar{\tau}_s$	=	average transmittance due to scattering,
$\bar{\tau}_t = \bar{\tau}_a \bar{\tau}_s$	=	average total transmittance,
$\bar{\tau}_a^b$, $\bar{\tau}_t^b$	=	average total transmittances from the observer to boundary,
$B(\bar{\nu}, T)$	=	average Planck (blackbody) function corresponding to the frequency $\bar{\nu}$ and the temperature T of an atmospheric layer,
T_b	=	temperature of the boundary.

The emissivity of the boundary is assumed to be unity.

The LOWTRAN band model approach used here assumes that since the blackbody function is a slowly varying function of frequency we can represent the average value of the radiance in terms of the average values of the transmittance and the blackbody function. $\bar{\tau}_a$, $\bar{\tau}_s$, and $\bar{\tau}_t$ vary from 1 to $\bar{\tau}_a^b$, $\bar{\tau}_s^b$, and $\bar{\tau}_t^b$ along the observers line-of-sight. For lines of sight which do not intersect the earth or a cloud layer, the second term in Eq. (1) is omitted.

The numerical analogue to Eq. (1) has been incorporated into the LOWTRAN 4 computer program. The numerical integration of the radiance along a line-of-sight for a given model atmosphere defined at N levels is given by

$$I(\bar{\nu}) = \sum_{i=1}^{N-1} \left(\bar{\tau}_a(i) - \bar{\tau}_a(i+1)\right) B\left(\bar{\nu}, \frac{T(i)+T(i+1)}{2}\right) \left(\frac{\bar{\tau}_s(i)+\bar{\tau}_s(i+1)}{2}\right) + B(\bar{\nu}, T_b)\bar{\tau}_t^b \tag{2}$$

Thus, the spectral radiance from a given atmospheric slant path (line-of-sight) can be calculated by dividing the atmosphere into a series of isothermal layers and summing the radiance contributions from each of the layers along the line-of-sight, that is, numerically evaluating Eq. (1). This can be clearly seen from the following simple example.

Neglecting scattering, consider a three-layered atmosphere characterized by temperatures T_1, T_2, and T_3 as shown in Figure 1. Let $\bar{\tau}_1$, $\bar{\tau}_2$, and $\bar{\tau}_3$ be the transmittances from the ground to the boundaries of each of the layers respectively (see Figure 1a). Figure 1b shows the corresponding case for an observer in space (distinguished by primed $\bar{\tau}$ values).

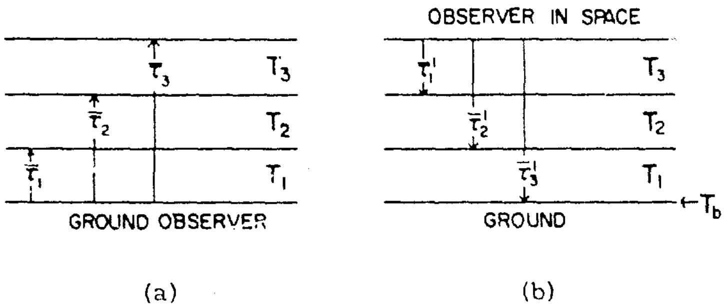

Figure 1. Upward and Downward Atmospheric Radiance Through a Three-Layered Atmosphere

Then from Eq. (2) the total downward spectral radiance for an observer on the ground (looking upwards) is given by

$$I(\bar{\nu})\downarrow = (1-\bar{\tau}_1)B(\bar{\nu}, T_1) + (\bar{\tau}_1-\bar{\tau}_2)B(\bar{\nu}, T_2) + (\bar{\tau}_2-\bar{\tau}_3)B(\bar{\nu}, T_3) \, . \tag{3}$$

Similarly for an observer looking down from the top of the atmosphere (see Figure 1b), the total upward spectral radiance is given by

$$I(\bar{\nu})\uparrow = (1-\bar{\tau}_1')B(\bar{\nu}, T_3) + (\bar{\tau}_1'-\bar{\tau}_2')B(\bar{\nu}, T_2) + (\bar{\tau}_2'-\bar{\tau}_3')B(\bar{\nu}, T_1) + \bar{\tau}_3' \, B(\bar{\nu}, T_b). \tag{4}$$

A comparison of Eqs. (3) and (4) shows that in addition to the boundary contributions to the total upward spectral radiance, the total downward and the total

upward spectral radiances from the same atmospheric layers are not the same but depend on the position of the observer relative to a given atmospheric slant path. In the LOWTRAN 4 radiance program, the position of the observer is always defined by the input parameter, H1 (see Section 6).

3. MODIFICATION OF TRANSMITTANCE FUNCTION

In the LOWTRAN 3/3B transmittance model,[1,2] the average transmittance $\bar{\tau}$ over a 20-cm^{-1} interval (due to molecular absorption) is represented by a single parameter model of the form

$$\bar{\tau} = f(C_\nu \omega^*) \tag{5}$$

where C_ν is a wavelength (or wavenumber) dependent absorption coefficient and ω^* is an "equivalent absorber amount" for the atmospheric path, which is defined in terms of the pressure P(z), temperature T(z), concentration of absorber ΔL, and an empirical constant n as follows

$$\omega^* = \Delta L \left\{ \frac{P(z)}{P_o} \sqrt{\frac{T_o}{T(z)}} \right\}^n . \tag{6}$$

If Eq. (6) is substituted in Eq. (5) and n is set to zero and unity, respectively, Eq. (5) reverts to the well known weak line and strong line approximations common to most band models.

The form of the function f and parameter n was determined empirically using both laboratory transmittance data and available molecular line constants. In both cases, the transmittance was degraded in resolution to 20 cm^{-1} throughout the entire spectral range covered here. It was found that the functions f for H_2O and the combined contributions of the uniformly mixed gases were essentially identical, although the parameter n differed in the two cases. Mean values of n were determined to be 0.9 for H_2O, 0.75 for the uniformly mixed gases, and 0.4 for ozone. For sufficiently small values of the argument $C_\nu \omega^*$, the transmittance in LOWTRAN 3B and earlier models was set to unity.

Since the LOWTRAN 4 program now calculates radiance as well as transmittance, the transmittance functions, f, were modified for radiance calculations from atmospheric layers of small optical thickness. For cases where $(0.999 \le \bar{\tau} \le 1)$ the transmittance functions now have the analytic form

$$\bar{\tau} = 1 - a(C_\nu \omega^*)^b \tag{7}$$

with $a = 0.088$ and $b = 0.81$ for H_2O and the uniformly mixed gases and $a = 0.055$ and $b = 1.03$ for ozone. This pseudo-linear approximation in Eq. (7) is used in the computer program for transmittances between 0.999 and 1.

The parameters a and b were determined from a least squares fit of the empirically derived transmittance function in Eq. (5).

4. NITRIC ACID

Measurements made from balloon flights[6], have shown the existence of nitric acid in the earth's atmosphere. Although nitric acid is of only minor importance in atmospheric transmittance calculations, it has been shown to be a significant source of stratospheric emission, particularly in the atmospheric window region from 10 to 12 μm. Therefore, nitric acid has been added to the LOWTRAN program as a separate atmospheric absorber.

The transmittance due to HNO_3 has been assumed to lie in the weak line or linear region. Absorption coefficients digitized at 5 cm^{-1} intervals for the 5.9 μm, 7.5 μm, and 11.3 μm bands of HNO_3 have been incorporated into the LOWTRAN program as a subroutine (SUBROUTINE HNO3). These coefficients were obtained by Goldman, Kyle, and Bonomo[7] by fitting their experimental results with the statistical band model approximation.

The concentration of atmospheric nitric acid varies with altitude and also appears to depend on latitude and season. Figure 2 shows the volume mixing ratio profile of atmospheric nitric acid as a function of altitude from the measurements of Evans, Kerr, and Wardle.[8] For the purpose of this report, we have chosen this profile to represent a mean nitric acid profile in the LOWTRAN program. This profile appears in a data statement in the main program. If a more definitive nitric acid profile for a given latitude and season is available, the user can change the nitric acid concentration by simply replacing the data statement given in the main program.

The inclusion of nitric acid as an additional absorber will modify somewhat transmittances from those calculated with the LOWTRAN 3B (1976) code in the spectral regions described above. Differences in transmittance values will only be significant for long atmospheric limb paths passing through the peak of the nitric acid profile.

6. Murcray, D.G., Kyle, T.G., Murcray, F.H., and Williams, W.G. (1968) Nitric acid and nitric oxide in the lower stratosphere. Nature 218:78.

7. Goldman, A., Kyle, T.G., and Bonomo, F.W. (1971) Statistical band model parameters and integrated intensities for the 5.9-μ, 7.5-μ, and 11.-3μ bands of HNO_3 vapor, Appl. Opt. 1:65.

8. Evans, W.F., Kerr, J.B., and Wardle, D.I. (1975) The AES Stratospheric Balloon Measurements Project: Preliminary Results, Atmospheric Environment Service, Downsview, Ontario, Canada, Report No. APRB 30 X 4.

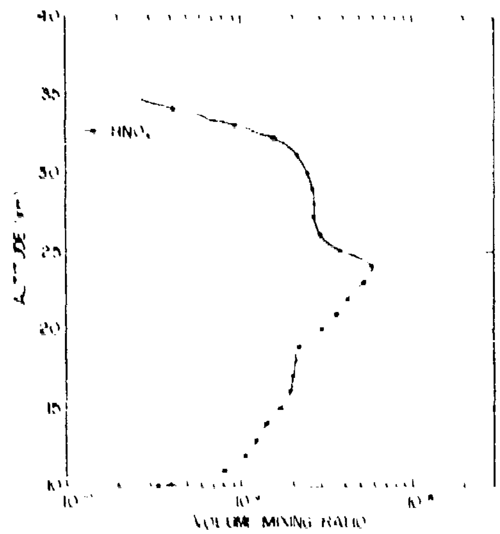

Figure 2. Volume Mixing Ratio of Atmospheric Nitric Acid as a Function of Altitude. See Reference 8

5. PROGRAM MODIFICATION

Program changes to the LOWTRAN 3/3B transmittance codes necessary for the conversion to a transmittance/radiance code were made in such a way as to preserve the logical flow in the original programs. Appendix A contains a listing of the FORTRAN computer code, LOWTRAN 4 together with the four subroutines, POINT, ANGLE, HNO3, and PATH. Although a new sequencing has been made in the code, the last column in the listing of Appendix A indicates the correspondence with the LOWTRAN 3B code. Changes in the code are indicated by the word, NEW, in the last column.

Two new subroutines have been added in the LOWTRAN 4 code. Subroutine PATH determines the cummulative absorber amounts through each of the layers intersected by the required atmospheric slant path. The amounts are stored in the matrix, WPATH, for each of the absorbing species. Subroutine HNO3 is called to find the nitric acid absorption coefficients as a function of frequency.

In the present program, a sample profile for the HNO_3 volume mixing ratio is provided in the data statement in the main program (DATA HMIX/...../). The altitudes of the mixing ratios correspond to those for the model atmosphere altitudes.

Only two new control parameters (IEMISS, TBOUND) have been added to the program. These parameters, included on the first control card, will be fully explained in the instructions given in Section 6.

6. INSTRUCTIONS FOR USING LOWTRAN 4

The instructions for using LOWTRAN 4, with the exception of a change in a single control card, are essentially the same as those for the LOWTRAN 3, 3B transmittance codes. In an attempt to make the instructions as clear as possible and to provide sufficient information for utilization of the computer code in this report, Section 5 of the LOWTRAN 3[2] report has been repeated here in its entirety. Changes in the instructions required for radiance calculations are indicated by bars in the margins.

The input data for LOWTRAN 4 are given in Appendix A. In general, it is only necessary to change the last four cards (referred to here as No's. 1-4) in order to run the program for a given problem. The formats for the last four cards and their application will be discussed.

6.1 Input Data and Formats

The data necessary to specify a given problem are given on the last four cards as follows:

CARD 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND	FORMAT (11I3, 2F10. 3)
CARD 2	H1, H2, ANGLE, RANGE, BETA, VIS	FORMAT (6F10. 3)
CARD 3	V1, V2, DV	FORMAT (3F10. 3)
CARD 4	IXY	FORMAT (I3)

Definitions of the above quantities will be discussed in Section 6. 2.

If the quantity MODEL given in CARD 1 is set equal to 0 or 7 (which is the case if meteorological data are used input to the program), then the above card sequence (and format for CARD 2) is changed. These cases will be described in Section 6. 3.

6.2 Basic Instructions

The various quantities to be specified on each of the four control cards (summarized in Section 6. 1) will be discussed in this section.

CARD 1 MODEL, IHAZE, ITYPE, LEN, JP, IM, M1, M2, M3, ML, IEMISS, RO, TBOUND

The parameter MODEL selects one of the six geographical model atmospheres or specifies that meteorological data are to be used in place of the standard models. IHAZE specifies whether aerosol attenuation is to be included in the calculation or not. For any problem the atmospheric path must be specified as one of three types according to ITYPE and LEN. IEMISS and TBOUND are new control parameters for radiance calculations. The rest of the quantities given on CARD 1 (which can be left blank if not required) provide the user with options to suppress printing (JP), to intermix the six standard model atmospheres (M1, M2, M3) and to input a new model atmosphere (IM, ML). The options for the above parameters and their uses are stated and described in detail below:

MODEL = 0 if meteorological data are specified (for horizontal paths only)†.
= 1 selects TROPICAL MODEL ATMOSPHERE.
= 2 selects MIDLATITUDE SUMMER.
= 3 selects MIDLATITUDE WINTER.
= 4 selects SUBARCTIC SUMMER.
= 5 selects SUBARCTIC WINTER.
= 6 selects 1962 U.S. STANDARD
= 7 if a new model atmosphere (or radiosonde data) is to be inserted.

IHAZE = 0 means no aerosol attenuation included in the calculations.
IHAZE = 1 or 2 if aerosol attenuation is required (see also CARD 2).

If IHAZE is set equal to 1 or 2 and visual range (VIS) is not specified on CARD 2, then the program will automatically select visual ranges of 23 km or 5 km respectively.

IHAZE = 7 Read other aerosol model into the program.
ITYPE = 1 for a horizontal (constant pressure) path.
2 for a vertical or slant path between two altitudes.
3 for a vertical or slant path to space.

---

† In these cases the format for Card 2 changes (see nonstandard conditions) Section 6.3.

The TYPE 1 path should not be confused with a long 90° path where the local height of the end of the trajectory is at a significantly different height. In such a case, specify the path according to ITYPE = 2.

LEN = 0 for normal operation of program.

LEN = 1 selects the downward TYPE 2 LONG path.

The parameter LEN can be ignored (that is, left blank) for the majority of cases. It need only be used for a downward looking path (H2 < H1) when two paths are possible for the same input parameters. In such a case, a computer printout statement will be given indicating that the user has two choices for the problem and that the shorter path has been executed. Set LEN = 1 for the longer case.

JP = 0 for normal operation of program

JP = 1 to suppress printing of transmittance table/or radiance table

IM = 1 when radiosonde data are to be read in initially

IM = 0 for normal operation of program or when subsequent calculations are to be run with MODEL = 7

ML = Number of levels to be read in for MODEL = 7

Note that IM and ML are only used when MODEL = 7 and then only on the first calculations when the data are read in.

M1 = M2 = M3 = 0 for normal operation of program.

The parameters M1, M2, and M3 can each take integral values between 0 and 6 and are used to modify or supplement the altitude profiles of temperature, water vapor, and ozone respectively, for any given atmospheric model specified by MODEL. For example:

M1 = 1 selects the TROPICAL temperature altitude profile

M1 = 2 selects the MIDLATITUDE SUMMER temperature altitude profile

M1 = 6 selects the 1962 U.S. STANDARD temperature altitude profile

M2 = 1 selects the TROPICAL water vapor altitude profile

M2 = 2 selects the MIDLATITUDE SUMMER water vapor altitude profile

M2 = 6 selects the 1962 U.S. STANDARD water vapor altitude profile

M3 = 1 selects the TROPICAL ozone altitude profile

M3 = 2 selects the MIDLATITUDE SUMMER ozone altitude profile

M3 = 6 selects the 1962 U.S. STANDARD ozone altitude profile.

The control parameter, IEMISS, determines the mode of execution of the program.

IEMISS = 0 for program execution in transmittance mode

IEMISS = 1 for program execution in radiance mode.

A message is printed to the user on the output file indicating the mode of program execution.

RO = radius of the earth (km) at the particular geographical location at which the calculation is to be performed.

If RO is left blank, the program will use the midlatitude value of 6371.23 km if MODEL is set equal to 0 or 7. Otherwise the earth radius for the appropriate standard model atmosphere (specified by MODEL) will be used.

TBOUND = temperature of the earth (°K) at the location at which the calculation is to be performed.

TBOUND is only used in the radiance mode of the program for slant paths which intersect the earth. If TBOUND is left blank, the program will use the temperature of the first atmospheric layer as the boundary temperature.

In the case where MODEL = 7, the new atmosphere (model or radiosonde data) is inserted between CARDS 1 and 2 (see Section 6.3).

CARD 2 H1, H2, ANGLE, RANGE, BETA, VIS

CARD 2 is used to define the geometrical path parameters for a given problem.

H1 = initial altitude (km)

H2 final altitude (km)

It is important to emphasize here that in the radiance mode of program execution (IEMSS 1), H1, the initial altitude, always defines the position of the observer (or sensor). H1 and H2 cannot be used interchangeably as in the transmittance mode.

ANGLE = initial zenith angle (degrees) as measured from H1

RANGE = path length (km)

BETA earth center angle subtended by H1 and H2 (degrees)

VIS sea level visual range (km).

It is not necessary to specify every quantity given above; only those that adequately describe the problem according to the parameter ITYPE (as described below):

(1) Horizontal Paths (ITYPE = 1)

(a) specify H1, RANGE and VIS only

(b) If nonstandard meteorological data are to be used, that is, if MODEL = 0 on CARD 1, then the following parameters must be specified on CARD 2: H1, P, T, DP, RH, WH, WO, VIS, RANGE according to FORMAT (3F10.3, 2F5.1, 2F10.3, 2F10.3), where P, T, DP, RH, WH, and WO are the pressure (mb), temperature (°C), dew point temperature (°C), relative humidity (%), H_2O density (gm m^{-3}) and ozone density (gm m^{-3}) respectively.

Note that it is necessary to specify all of the quantities underlined with a full line and one of the quantities underlined with a dashed line. If the ozone density (WO) is not known, a value can be chosen from one of the standard atmospheric models by using the parameter M3 on CARD 1.

(2) Slant Paths to Space (ITYPE = 3)

(a) specify H1, ANGLE and VIS

(b) specify H1, HMIN and VIS (for limb viewing problem where HMIN is the required tangent height or minimum altitude of the path trajectory.

(3) Slant Paths Between Two Altitudes (ITYPE = 2)

(a) specify H1, H2, ANGLE and VIS

(b) specify H1, ANGLE, RANGE and VIS

(c) specify H1, H2, RANGE and VIS

For cases (b) and (c), the program will calculate H2 and ANGLE respectively, assumming no refraction; then proceed as for case (a). This method of defining the problem should be used when refraction effects are not important; for example, for ranges of a few tens of km at zenith angles less than 80°. It can also be used for larger angles (including 90°) provided that the path lies within one atmospheric layer.

(d) Specify H1, H2, BETA and VIS. Leave ANGLE and RANGE blank in this case. This method can be used when the geometrical configuration of the source and receiver is known accurately, but the initial zenith angle is not known precisely due to atmospheric refraction effects. Beta is most frequently determined by the user from ground range information.

In the cases of 2(b) and 3(d) above, the subroutine ANGLE is called in the program to determine the appropriate input zenith angle by an iterative technique taking into account atmospheric refraction.

In the case where MODEL = 7, the new model atmosphere (or radiosonde data) is inserted between CARDS 1 and 2.

CARD 3 V1, V2, DV

The spectral range over which transmittance data are required and the spectral increments at which the data are to be printed out is determined by CARD 3.

V1 = initial frequency in wavenumbers (cm^{-1})

V2 = final frequency in wavenumbers (cm^{-1}) where V2 > V1

DV = frequency increment (or step size) (cm^{-1})

(Note that $\nu = 10^4/\lambda$ where ν is the frequency in cm^{-1} and λ is the wavelength in microns, and that DV can <u>only</u> take values which are a multiple of 5.)

CARD 4 IXY

The control parameter IXY can cause the program to recycle, so that a series of problems can be run with one submission of LOWTRAN. Five values of IXY can be used to provide the options given on the following pages.

IXY = 0 or blank card to end of program

= 1 to select a new CARD 3 and CARD 4 only (assuming other parameters are unchanged)

2 to select a new data sequence (CARDS 1, 2, 3, and 4)

= 3 to select a new CARD 2 and CARD 4 only (assuming other parameters are unchanged)

= 4 to select a new CARD 1 and CARD 4 only (assuming other parameters are unchanged)

Thus, if for the same model atmosphere and type of atmospheric path the reader wishes to make further transmittance calculations in different spectral intervals V1' to V2' etc. and for a different step size (DV' etc.), then IXY is set equal to 1. In this case, the card sequence is as follows and can be repeated as many times as required.

CARD 4	IXY = 1
CARD 5	V1' V2' DV'
CARD 6	IXY = 1
CARD 7	V1'' V2'' DV''
CARD 8	IXY = 0

The final IXY card should always be a blank or zero. When using the IXY = 1 option, the wavelength dependence of the refractive index is not changed (use IXY = 2 option if this is required).

To make successive transmittance computations where just the geographical model atmosphere is changed and/or with or without aerosol attenuation, set IXY = 4 and construct a data card sequence along the same lines as given above. This sequence of recycling can be repeated successively.

When a series of problems is to be executed (with one submission of LOWTRAN) involving the standard atmospheric models (MODEL = 1 to 6) as well as cases involving MODEL = 0 and MODEL = 7, then the order in which the data are set up becomes very important. Note the following sequence.

1. Run all problems using MODEL = 1 through 6 first.

2. Secondly, run all problems involving the use of MODEL = 0.

3. Run all problems involving the use of MODEL = 7 last. The reason for running MODEL = 7 cases last is that when a new atmospheric model is read in, the altitudes may not correspond with those given in the standard models and the program will erase them. Similarly, if a MODEL = 0 case is run following a MODEL = 7 case, the first level of MODEL 7 is erased.

6.3 Non-Standard Conditions

Three options are available if atmospheric transmittance calculations are required for non-standard conditions. Here non-standard refers to conditions other

than those specified by the six model atmospheres provided by LOWTRAN, which are selected by the parameter MODEL on CARD 1. The three options enable the reader to insert:

(1) His own model atmosphere(s) in place of any (or all) of the six standard models, provided that the data are in exactly the same format and are specified at the same altitudes as the latter. In this case the appropriate print statements in LOWTRAN (that identify the atmospheric model used) must be changed correspondingly.

(2) An additional atmospheric model (MODEL 7), which can be in the form of radiosonde data. The data need not be specified at the same altitudes as in the standard models.

(3) Meteorological conditions for a given horizontal path calculation (MODEL = 0 case).

The first of these options requires the most effort and needs no farther discussion here, other than a reference to Appendix A for a summary of the standard model atmosphere parameters, units, and formats.

ADDITIONAL ATMOSPHERIC MODEL (MODEL = 7)

New model atmospheres can be inserted between CARDS 1 and 2 provided the parameters MODEL and IM are set equal to 7 and 1 respectively on CARD 1. The number of atmospheric levels to be inserted (ML) must also be specified on CARD 1. The appropriate meteorological parameters and format for the atmospheric data are given below.

Z, P, T, DP, RH, WH, WO, AHAZE [FORMAT (3F10.3, 2F5.1, 2F10.3, 2F10.3)] where

Z	=	altitude (km)
P		pressure (mb)
T		ambient temperature (°C)
DP		dew point temperature (°C)
RH		relative humidity (%)
WH		water vapor density (gm m^{-3})
WO		ozone density (gm m^{-3})
AHAZE		aerosol number density (cm^{-3})

Note that it is only necessary to specify those quantities underlined with a full line and either of the quantities underlined with the dashed line.

If the ozone density (WO) is not known then a value can be obtained from one of the standard atmospheric models (for the appropriate latitude and season) by using the parameter M3 on CARD 1.

If the aerosol number density was not measured as a function of altitude and the reader wishes to include aerosol attenuation in the calculation, set IHAZE = 1 on CARD 1. In this case (as with the M1, M2, and M3 options) LOWTRAN will use the aerosol models already contained in the program and interpolate to give aerosol number density values at the same altitudes as the radiosonde (or new model atmosphere) data. The program will then look for a sea level visual range (VIS) to be specified on CARD 2. If VIS is not specified, a 23 km sea level visual range will be assumed. If aerosol attenuation is not required, set IHAZE = 0 on CARD 1 as before.

HORIZONTAL PATHS (MODEL = 0)

If meteorological data are to be used for horizontal path atmospheric transmittance calculations, then set MODEL = 0 on CARD 1. The following parameters can then be specified on CARD 2:

CARD 2 H1, P, T, DP, RH, WH, WO, VIS, RANGE [FORMAT (3, F10.3, 2F5.1, 2F10.3, 2F10.3)] where the above parameters refer to altitude (km), pressure (mb) ambient temperature (°C), dew point temperature (°C), relative humidity (%), water vapor density (gm m^{-3}), ozone density (gm m^{-3}), visual range (km) and path length (km) respectively.

The format for the above card is similar to that for inputting radiosonde data (MODEL = 7). Again, it is only necessary to specify the quantities underlined with the solid line and one of the quantities underlined with the dashed line. The ozone density WO can be specified using the parameter M3 on CARD 1 if measurements are not available. In the latter case, a value will be calculated at altitude H1 based on the appropriate model atmosphere selected by M3.

7. EXAMPLE OF PROGRAM USE

7.1 Problem

Calculate the transmittance from 2350 to 2450 cm^{-1} in steps of 5 cm^{-1} for a slant path from 2.5 km to 8.5 km at a zenith angle of 65°, for a subarctic winter model atmosphere, and a 23 km visual range. Repeat the calculation for the same conditions executing the program in the radiance mode.

CARD 1 **5**1**2

CARD 2 ******2.50******8.50******65.0

CARD 3 ****2350.0****2450.0******5.0

CARD 4 **4

CARD 5 **5**1**23**********************1(Column 33)

CARD 6 BLANK

(* represents a space on the card)

7.2 Output from LOWTRAN 4

The output for this problem is given in Table 1. A message indicating the mode of execution of the program is printed as the first line of the output. For this problem, the first case will be executed in the transmittance mode.

The parameters defining the atmospheric path, model atmospheres and frequency range are next printed out. Following the heading HORIZONTAL PROFILES there are 13 columns. The first column gives a running integer associated with each level (level indicator). The second column gives the level altitude in km. The next 8 columns give the equivalent absorber amounts per km for the following absorbing species: water vapor, uniformly mixed gases, ozone, nitrogen, continuum, water vapor continuum (10 μm), molecular scattering, aerosol extinction[1] and UV ozone, respectively. The next three columns give the mean refractive index modulus from that level to the level above, the equivalent absorber amounts per km for the water vapor continuum (4 μm) and for nitric acid.

A heading VERTICAL PROFILES is then printed followed by 15 columns. The first and second columns give the integer associated with the levels traversed by the path and the height of the level. Then follow 8 columns which give the integrated equivalent absorber amounts from the initial altitude to the level above (in the same order as indicated above). The next 4 columns are labelled PSI, PHI, BETA, and THETA, and correspond to the angles similar to ψ, ϕ, β, and θ described in LOWTRAN 3.[2] Columns PSI and BETA give the accumulated values of ψ and β to the level above. Columns THETA and PHI give the local zenith angle θ_1 corresponding to that level and the angle of arrival at the level above, respectively. The accumulated slant range is printed out in the last column under RANGE.

The total equivalent absorber amounts for each absorber species are then summarized below in their appropriate units.

The second line in the total equivalent absorber amount table gives the water vapor continuum amount (4 μm) and the nitric acid amount.

A transmittance table, containing 12 columns, now follows. The first 3 columns give the frequency (cm^{-1}) wavelength (μm), and total transmittance. The next 7 columns show the individual transmittance due to water vapor, uniformly mixed gases, ozone, nitrogen (4 μm) continuum, total water vapor continuum, molecular scattering, and aerosol extinction. The last 2 columns give absorption due to aerosols and the cumulative integrated absorption. The latter quantity can be used to determine the average transmittance over any given spectral interval within the spectral range covered by the calculation. Finally, the total integrated absorption from V1 to V2 is printed out (units are cm^{-1}) together with the average transmittance over the band.

---

[1] For all radiance calculations in this report, the average continental aerosol model was used.

Table 1. Typical Output of LOWTRAN 4

```
PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE
5  1  2  0  0  2  0  0  0  0  1      0.000      0.000
            2.500      8.500     65.000      0.000      0.000      0.000
       H1=  2.500KM,H2=  8.500KM,ANGLE= 65.0000GEOM. RANGE =  14.17KM,BETA=  .11557,VIS=   0.0
2350.000  2450.000      5.000
```

SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 = 2.500 KM H2 = 8.501 KM,ZENITH ANGLE = 65.000 DEGREES

MODEL ATMOSPHERE 5 = SUB-ARCTIC WINTER

HAZE MODEL 1 = 23 KM VISUAL RANGE

FREQUENCY RANGE V1= 2350.0 CM-1 TO V2= 2450.0 CM-1 FOR DV = 5.0 CM-1 (4.08 - 4.26 MICRONS)

HORIZONTAL PROFILES

1	0.0	.123E+00	.109E+01	.194E-02	.876E+00	.663E-03	.106E+01	.100E+01	.191E-02	.285E-03	.293E-01	0.
2	1.0	.109E+00	.854E+00	.183E-02	.665E+00	.614E-03	.924E+00	.443E+00	.191E-02	.250E-03	.244E-01	0.
3	2.0	.763E-01	.688E+00	.174E-02	.520E+00	.411E-13	.619E+00	.190E+00	.191E-02	.222E-03	.179E-01	0.
4	3.0	.492E-01	.554E+00	.174E-02	.405E+00	.242E-03	.725E+00	.798E-01	.201E-02	.197E-03	.121E-01	0.
5	4.0	.265E-01	.448E+00	.173E-02	.318E+00	.110E-03	.646E+00	.422E-01	.212E-02	.176E-03	.705E-02	0.
6	5.0	.115E-01	.365E+00	.172E-02	.250E+00	.380E-04	.577E+00	.318E-01	.219E-02	.157E-03	.348E-02	0.
7	6.0	.503E-02	.295E+00	.170E-02	.195E+00	.138E-04	.515E+00	.224E-01	.229E-02	.140E-03	.173E-02	0.
8	7.0	.246E-02	.237E+00	.234E-02	.152E+00	.601E-05	.457E+00	.208E-01	.331E-02	.124E-03	.979E-03	0.
9	8.0	.442E-03	.189E+00	.280E-02	.118E+00	.516E-06	.404E+00	.215E-01	.420E-02	.109E-03	.205E-03	.434E-54
10	9.0	.295E-03	.147E+00	.469E-02	.890E-01	.533E-06	.351E+00	.206E-01	.747E-02	.936E-04	.147E-03	.551E-45
11	10.0	.168E-03	.112E+00	.661E-02	.643E-01	.290E-16	.300E+00	.201E-01	.112E-01	.800E-04	.824E-04	.991E-35
12	11.0	.101E-03	.849E-01	.828E-02	.470E-01	.158E-06	.257E+00	.188E-01	.149E-01	.684E-04	.467E-04	.205E-04
13	12.0	.598E-04	.645E-01	.104E-01	.343E-01	.967E-07	.219E+00	.197E-01	.231E-01	.584E-04	.284E-04	.253E-04
14	13.0	.360E-04	.490E-01	.107E-01	.251E-01	.566E-07	.187E+00	.167E-01	.219E-01	.500E-04	.163E-04	.262E-04
15	14.0	.174E-04	.373E-01	.105E-01	.183E-01	.264E-07	.160E+00	.179E-01	.229E-01	.427E-04	.800E-05	.255E-04
16	15.0	.115E-04	.283E-01	.113E-01	.134E-01	.171E-07	.137E+00	.168E-01	.261E-01	.365E-04	.519E-05	.246E-04
17	16.0	.839E-05	.216E-01	.117E-01	.982E-02	.123E-07	.117E+00	.160E-01	.289E-01	.313E-04	.362E-05	.223E-04
18	17.0	.638E-05	.165E-01	.110E-01	.720E-02	.920E-08	.101E+00	.158E-01	.289E-01	.268E-04	.249E-05	.201E-04
19	18.0	.495E-05	.125E-01	.103E-01	.527E-02	.703E-08	.862E-01	.153E-01	.289E-01	.230E-04	.225E-05	.161E-04
20	19.0	.421E-05	.954E-02	.941E-02	.385E-02	.592E-08	.738E-01	.128E-01	.284E-01	.197E-04	.191E-05	.170E-04
21	20.0	.336E-05	.726E-02	.824E-02	.282E-02	.466E-08	.631E-01	.943E-02	.261E-01	.165E-04	.153E-05	.129E-04
22	21.0	.330E-05	.551E-02	.705E-02	.206E-02	.457E-08	.540E-01	.684E-02	.236E-01	.144E-04	.150E-05	.200E-04
23	22.0	.286E-05	.419E-02	.610E-02	.151E-02	.394E-08	.462E-01	.514E-02	.219E-01	.123E-04	.130E-05	.134E-04
24	23.0	.263E-05	.318E-02	.524E-02	.110E-02	.362E-08	.395E-01	.394E-02	.201E-01	.105E-04	.122E-05	.205E-04
25	24.0	.253E-05	.241E-02	.412E-02	.801E-03	.353E-08	.337E-01	.312E-02	.168E-01	.898E-05	.115E-05	.202E-04
26	25.0	.245E-05	.183E-02	.343E-02	.584E-03	.348E-08	.288E-01	.263E-02	.149E-01	.597E-05	.112E-05	.104E-04
27	30.0	.638E-06	.442E-03	.117E-02	.115E-03	.846E-09	.127E-01	.791E-03	.700E-02	.265E-05	.136E-06	.331E-05
28	35.0	.959E-07	.110E-03	.522E-03	.235E-04	.111E-09	.570E-02	.208E-03	.429E-02	.113E-05	.274E-07	.126E-06
29	40.0	.188E-07	.278E-04	.171E-03	.492E-05	.230E-10	.258E-02	.548E-04	.191E-02	.545E-06	.376E-08	.256E-06
30	45.0	.432E-08	.761E-05	.406E-04	.112E-05	.431E-11	.122E-02	.144E-04	.607E-03	.260E-06	.619E-09	0.
31	50.0	.769E-09	.222E-05	.102E-04	.276E-06	.722E-12	.595E-03	.381E-05	.201E-03	.918E-07	.614E-10	0.
32	70.0	.160E-11	.229E-07	.711E-07	.147E-06	.112E-14	.441E-04	.196E-07	.401E-15	.579E-08	.159E-12	0.
33	100.0	.150E-15	.540E-11	.518E-11	.104E-12	[illegible]	.385E-06	.396E-11	.201E-08	.597E-10	.230E-16	0.
34	******	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
FROM POINT1 HEIGHT=    2.5000 KM,N=  3,NP= 0,REF. INDEX ABOVE & BELOW X=  .2150E-03  .2284E-03,IP=  1
     EQUIV. ABSORBER AMOUNTS PER KM AT X=  .613E-01  .617E+00  .174E-02  .459E+00  .316E-03  .771E+00  .123E+00  .196E-02

FROM POINT1 HEIGHT=    8.5006 KM,N=  9,NP= 0,REF. INDEX ABOVE & BELOW X=  .1046E-03  .1122E-03,IP=  1
     EQUIV. ABSORBER AMOUNTS PER KM AT X=  .361E-03  .167E+00  .363E-02  .102E+00  .659E-05  .377E+00  .216E-01  .560E-02
```

Table 1. Typical Output of LOWTRAN 4 (Cont)

VERTICAL PROFILES

										PSI	PHI	BETA	THETA	RANGE
3	2.5	.651E-01	.692E+00	.206E-02	.516E+01	.328E-03	.885E+00	.118E+00	.235E-02	-.0000	115.0097	.0097	65.[illegible]	1.2
4	3.0	.152E+00	.187E+01	.616E-02	.136E+01	.724E-03	.250E+01	.258E+00	.720E-02	.0022	115.0268	.0290	64.9923	3.6
5	4.0	.194E+00	.283E+01	.102E-01	.203E+01	.684E-03	.395E+01	.344E+00	.123E-01	.0046	115.0434	.0462	64.9755	5.9
6	5.0	.213E+00	.361E+01	.143E-01	.255E+01	.941E-03	.524E+01	.408E+00	.176E-01	.0071	115.0604	.0675	64.9589	[illegible]
7	6.0	.221E+00	.423E+01	.190E-01	.296E+01	.963E-03	.638E+01	.459E+00	.241E-01	.0092	115.0775	.0868	64.9417	[illegible]
8	7.0	.224E+00	.473E+01	.250E-01	.328E+01	.959E-03	.745E+01	.509E+00	.329E-01	.0112	115.0946	.1061	64.9244	[illegible]
9	8.0	.224E+00	.494E+01	.288E-01	.341E+01	.976E-03	.786E+01	.534E+00	.387E-01	.0126	115.1030	.1156	64.9[illegible]	[illegible]

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(UV) ATM CM NITRIC ACID
W(1-8)=	.224E+05	.494E+01	.288E-01	.341E+01	.970E-03 .536E-01	.786E+01	.534E+00	.387E-01 .249E-01

FREQ CM-1	WAVELENGTH MICRONS	TOTAL TRANS	H2O TRANS	CO2+ TRANS	OZONE TRANS	N2 CONT TRANS	H2O CONT TRANS	MOL SCAT TRANS	AEROSOL TRANS	AEROSOL ABS	INTEGRATED ABSORPTION
2350	4.2553	0.0000	.9965	0.0000	1.0000	.6576	1.0000	1.0000	.9907	.0011	2.5000
2355	4.2463	0.0000	.9970	0.0000	1.0000	.6666	.9989	1.0000	.9907	.0011	7.5000
2360	4.2373	0.0000	.9973	0.0000	1.0000	.6735	.9978	1.0000	.9907	.0011	12.5000
2365	4.2283	0.0000	.9974	0.0000	1.0000	.6781	.9966	1.0000	.9907	.0011	17.5000
2370	4.2194	0.0000	.9977	0.0000	1.0000	.6827	.9955	1.0000	.9907	.0011	22.5000
2375	4.2105	0.0000	.9976	0.0000	1.0000	.6827	.9944	1.0000	.9907	.0011	27.5000
2380	4.2017	.0015	.9981	.0022	1.0000	.6850	.9933	1.0000	.9907	.0010	32.4927
2385	4.1929	.0277	.9984	.0413	1.0000	.6850	.9921	1.0000	.9906	.0010	37.3541
2390	4.1841	.1111	.9988	.1553	1.0000	.6827	.9910	1.0000	.9906	.0010	41.7964
2395	4.1754	.2567	.9990	.3864	1.0000	.6781	.9899	1.0000	.9905	.0010	45.5119
2400	4.1667	.4559	.9991	.6847	1.0000	.6804	.9888	1.0000	.9905	.0010	48.2323
2405	4.1580	.5867	.9993	.8775	1.0000	.6827	.9890	1.0000	.9906	.0010	50.2355
2410	4.1494	.6655	.9995	.9851	1.0000	.6897	.9893	1.0000	.9906	.0010	51.9711
2415	4.1408	.6763	.9995	.9949	1.0000	.6945	.9895	1.0000	.9906	.0010	53.5835
2420	4.1322	.6866	.9995	.9919	1.0000	.7054	.9898	1.0000	.9905	.0010	55.1566
2425	4.1237	.6906	.9996	.9875	1.0000	.7136	.9900	1.0000	.9905	.0009	56.7027
2430	4.1152	.6961	.9996	.9813	1.0000	.7234	.9902	1.0000	.9905	.0009	58.2225
2435	4.1068	.7329	.9997	.9743	1.0000	.7359	.9905	1.0000	.9905	.0009	59.7050
2440	4.0984	.7080	.9998	.9690	1.0000	.7447	.9907	1.0000	.9905	.0009	61.1682
2445	4.0900	.7179	.9998	.9662	1.0000	.7562	.9909	1.0000	.9905	.0009	62.5832
2450	4.0816	.7295	.9998	.9645	1.0000	.7735	.9912	1.0000	.9905	.0009	63.2595

INTEGRATED ABSORPTION FROM 2350 TO 2450 CM-1 = 63.26,AVERAGE TRANSMITTANCE = .3674

Table 1. Typical Output of LOWTRAN 4 (Cont)

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

```
PROGRAM WILL BE EXECUTED IN THE EMISSION MODE
5  1  2  0  0  5  3  0  0  0  1      0.000      0.000

        SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 =  2.500 KM H2 =  8.500 KM,ZENITH ANGLE = 65.000 DEGREES

                MODEL ATMOSPHERE 5 = SUB-ARCTIC WINTER

                    HAZE MODEL 1 = 23 KM VISUAL RANGE

        FREQUENCY RANGE V1=  2350.0 CM-1 TO V2=  2450.0 CM-1 FOR DV =   5.0 CM-1   ( 4.08 -  4.26 MICRONS )
```

HORIZONTAL PROFILES

1	0.0	.123E+00	.109E+01	.194E-02	.876E+00	.663E-03	.106E+01	.100E+01	.191E-02	.285E-03	.293E-01	0.
2	1.0	.103E+00	.854E+00	.183E-02	.665E+00	.614E-03	.924E+00	.440E+00	.191E-02	.250E-03	.244E-01	0.
3	2.0	.763E-01	.686E+00	.174E-02	.520E+00	.411E-03	.819E+00	.190E+00	.191E-02	.222E-03	.173E-01	0.
4	3.0	.492E-01	.554E+00	.174E-02	.405E+00	.242E-03	.725E+00	.798E-01	.201E-02	.197E-03	.121E-01	0.
5	4.0	.265E-01	.444E+00	.173E-02	.318E+00	.110E-03	.646E+00	.422E-01	.210E-02	.175E-03	.745E-02	0.
6	5.0	.119E-01	.365E+00	.172E-02	.250E+00	.380E-04	.577E+00	.318E-01	.219E-02	.157E-03	.346E-02	0.
7	6.0	.553E-02	.295E+00	.170E-02	.196E+00	.138E-04	.515E+00	.224E-01	.229E-02	.140E-03	.173E-02	0.
8	7.0	.245E-02	.237E+00	.234E-02	.152E+00	.601E-05	.457E+00	.206E-01	.331E-02	.124E-03	.973E-03	0.
9	8.0	.442E-03	.189E+00	.280E-02	.118E+00	.316E-05	.404E+00	.215E-01	.420E-02	.113E-03	.258E-03	.404E-04
10	9.0	.295E-03	.147E+00	.469E-02	.885E-01	.537E-06	.351E+00	.206E-01	.747E-02	.436E-04	.147E-03	.351E-04
11	10.0	.168E-03	.112E+00	.651E-02	.647E-01	.299E-06	.301E+00	.201E-01	.112E-01	.600E-04	.624E-04	.991E-04
12	11.0	.101E-03	.849E-01	.828E-02	.472E-01	.169E-06	.257E+00	.199E-01	.149E-01	.654E-04	.457E-04	.205E-04
13	12.0	.598E-04	.645E-01	.104E-01	.343E-01	.967E-07	.219E+00	.197E-01	.201E-01	.554E-04	.454E-04	.263E-04
14	13.0	.360E-04	.490E-01	.107E-01	.251E-01	.566E-07	.187E+00	.182E-01	.219E-01	.500E-04	.160E-04	.252E-04
15	14.0	.174E-04	.373E-01	.105E-01	.183E-01	.264E-07	.160E+00	.173E-01	.229E-01	.427E-04	[illegible]	.295E-04
16	15.0	.115E-04	.283E-01	.113E-01	.134E-01	.171E-07	.137E+00	.165E-01	.261E-01	.369E-04	.519E-05	.346E-04
17	16.0	.839E-05	.216E-01	.117E-01	.982E-02	.123E-07	.117E+00	.161E-01	.289E-01	.323E-04	.769E-05	.223E-04
18	17.0	.638E-05	.165E-01	.110E-01	.720E-02	.920E-08	.101E+00	.156E-01	.269E-01	.285E-04	.254E-05	.241E-04
19	18.0	.495E-05	.125E-01	.103E-01	.527E-02	.703E-08	.862E-01	.153E-01	.265E-01	.230E-04	.225E-05	.151E-04
20	19.0	.421E-05	.954E-02	.941E-02	.386E-02	.592E-08	.738E-01	.125E-01	.260E-01	.157E-04	.191E-05	.170E-04
21	20.0	.336E-05	.726E-02	.824E-02	.282E-02	.466E-08	.631E-01	.943E-02	.261E-01	.149E-04	.153E-05	.189E-04
22	21.0	.330E-05	.551E-02	.705E-02	.206E-02	.457E-08	.540E-01	.604E-02	.235E-01	.144E-04	.150E-05	.200E-04
23	22.0	.285E-05	.419E-02	.615E-02	.151E-02	.194E-08	.462E-01	.514E-02	.219E-01	.123E-04	.130E-05	.144E-04
24	23.0	.263E-05	.318E-02	.524E-02	.113E-02	.362E-08	.395E-01	.394E-02	.201E-01	.105E-04	.122E-05	.105E-04
25	24.0	.253E-05	.241E-02	.412E-02	.811E-03	.153E-08	.337E-01	.312E-02	.168E-01	.995E-05	.115E-05	.102E-04
26	25.0	.245E-05	.183E-02	.343E-02	.584E-03	.745E-08	.288E-01	.263E-02	.149E-01	.537E-05	.112E-05	.104E-04
27	30.0	.638E-06	.442E-03	.117E-02	.115E-03	.546E-09	.127E-01	.791E-03	.760E-02	.265E-05	.336E-06	.551E-05
28	35.0	.359E-07	.110E-03	.922E-03	.235E-04	.111E-09	.575E-02	.206E-03	.429E-02	.113E-05	.279E-07	.128E-05
29	40.0	.138E-07	.278E-04	.171E-03	.492E-05	.203E-10	.255E-02	.544E-04	.191E-02	.545E-06	.776E-08	.255E-06
30	45.0	.432E-08	.761E-05	.406E-04	.112E-05	.431E-11	.122E-02	.144E-04	.607E-03	.260E-06	.613E-09	0.
31	50.0	.769E-09	.222E-05	.107E-04	.276E-06	.722E-12	.595E-03	.381E-05	.201E-03	.918E-07	.814E-11	0.
32	70.0	.160E-11	.229E-07	.711E-07	.147E-08	.112E-14	.441E-04	.135E-07	.401E-05	.673E-09	.169E-12	0.
33	100.0	.150E-15	.540E-11	.516E-11	.104E-12	.604E-19	.365E-06	.696E-11	.201E-06	.553E-10	.240E-16	0.
34	******	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
FROM POINT: HEIGHT=    2.5000 KM,N=  3,NP= 3,REF. INDEX ABOVE & BELOW X=  .2150E-03  .2284E-03,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .613E-01  .617E+00  .174E-02  .459E+00  .316E-03  .771E+00  .123E+00  .196E-02

FROM POINT: HEIGHT=    6.5000 KM,N=  9,NP= 9,REF. INDEX ABOVE & BELOW X=  .1046E-03  .1122E-03,IP=  1
        EQUIV. ABSORBER AMOUNTS PER KM AT X=  .361E-03  .167E+00  .363E-02  .102E+00  .659E-06  .377E+00  .210E-01  .560E-02
```

Table 1. Typical Output of LOWTRAN 4 (Cont)

VERTICAL PROFILES

										PSI	PHI	BETA	THETA	RANGE
3	2.5	.651E-01	.692E+00	.206E-02	.510E+01	.328E-03	.865E+00	.118E+00	.235E-02	-.0000	115.0197	.0097	65.0000	1.2
4	3.0	.152E+00	.187E+01	.616E-02	.136E+01	.724E-03	.250E+01	.258E+00	.720E-02	.0022	115.0268	.0230	64.9925	3.5
5	4.0	.194E+00	.283E+01	.102E-01	.203E+01	.884E-03	.395E+01	.344E+00	.123E-01	.0048	115.0434	.0452	64.[illegible]	5.9
6	5.0	.213E+00	.361E+01	.143E-01	.255E+01	.941E-03	.524E+01	.408E+00	.176E-01	.0071	115.0600	.0675	64.9589	8.3
7	6.0	.221E+00	.423E+01	.190E-01	.296E+01	.963E-03	.638E+01	.459E+00	.241E-01	.0092	115.0775	.0868	64.9417	10.5
8	7.0	.224E+00	.473E+01	.250E-01	.328E+01	.969E-03	.740E+01	.509E+00	.329E-01	.0112	115.0948	.1063	64.9244	12.6
9	8.0	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03	.786E+01	.534E+00	.387E-01	.0125	115.1030	.1156	64.9000	14.2

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOUR GM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	MOL SCAT KM	AEROSOL KM	OZONE(U-V) ATM CM / NITRIC ACID
W(1-8)=	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03 .602E-01	.786E+01	.534E+00	.387E-01 .249E-31

3 9

CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH

	H2O	CO2+	O3	N2	H2O C	MOL S	AERO	O3 UV	H2O C	HNO3	TAVE
1	.651E-01	.692E+00	.206E-02	.510E+00	.328E-03	.865E+00	.118E+00	.235E-02	.158E-01	0.	254.300
2	.152E+00	.187E+01	.616E-02	.136E+01	.724E-03	.250E+01	.258E+00	.720E-02	.376E-01	0.	250.2[illegible]
3	.194E+00	.283E+01	.102E-01	.203E+01	.884E-03	.39[illegible]	.344E+00	.123E-01	.498E-01	0.	244.300
4	.213E+00	.361E+01	.143E-01	.255E+01	.941E-03	.52[illegible]	.408E+00	.176E-01	.557E-01	0.	237.500
5	.221E+00	.423E+01	.190E-01	.296E+01	.963E-03	.63[illegible]	.459E+00	.241E-01	.588E-01	0.	230.7[illegible]
6	.224E+00	.473E+01	.250E-01	.328E+01	.969E-03	.740[illegible]	.509E+00	.329E-01	.600E-01	0.	223.350
7	.224E+00	.494E+01	.288E-01	.341E+01	.970E-03	.786E+01	.534E+00	.387E-01	.602E-01	.249E-31	216.900

RADIANCE(WATTS/CM2-STER-XXX)

FR(CM-1)	WVL(MICRON)	PER CM-1	PER MICRON	INTEGRAL	TRANS
2350.0	4.255319	.25963E-07	.14338E-04	.64907E-07	0.000000
2355.0	4.246285	.25400E-07	.14087E-04	.19191E-06	0.000000
2360.0	4.237288	.24849E-07	.13840E-04	.31615E-06	0.000000
2365.0	4.228330	.24310E-07	.13597E-04	.43770E-06	0.000000
2370.0	4.219409	.23770E-07	.13351E-04	.55655E-06	0.000000
2375.0	4.210526	.23159E-07	.13063E-04	.67235E-06	0.000000
2380.0	4.201681	.21965E-07	.12442E-04	.78217E-06	.001453
2385.0	4.192872	.19453E-07	.11066E-04	.87944E-06	.027733
2390.0	4.184100	.16113E-07	.92040E-05	.96000E-06	.111738
2395.0	4.175365	.12103E-07	.69424E-05	.10205E-05	.256694
2400.0	4.166667	.77927E-08	.44865E-05	.10595E-05	.455931
2405.0	4.158004	.53029E-08	.30672E-05	.10860E-05	.58[illegible]4
2410.0	4.149378	.39715E-08	.23067E-05	.11059E-05	.665477
2415.0	4.140787	.37388E-08	.21806E-05	.11246E-05	.676333
2420.0	4.132231	.35305E-08	.20676E-05	.11422E-05	.686569
2425.0	4.123711	.34011E-08	.20000E-05	.11592E-05	.690779
2430.0	4.115226	.32756E-08	.19342E-05	.11756E-05	.696025
2435.0	4.106776	.31329E-08	.18575E-05	.11913E-05	.702917
2440.0	4.098361	.30144E-08	.17947E-05	.12063E-05	.707968
2445.0	4.089980	.28492E-08	.17033E-05	.12206E-05	.717006
2450.0	4.081633	.26555E-08	.15940E-05	.12272E-05	.729462

RADMIN 2450.000 .26555E-08
RADMAX 2350.000 .25963E-07
INTEGRATED ABSORPTION FROM 2350 TO 2450 CM-1 = 63.26,AVERAGE TRANSMITTANCE = .3674
INTEGRATED RADIANCE = .12272E-05WATT CM -2 SR
0

The second case is now executed for the same conditions in the radiance mode. The output of the program is identical to the transmittance mode up to and including the printing of the equivalent sea level absorber amounts.

Two parameters, J1 and J2, are then printed out. These parameters control the loading of the cumulative absorber amounts into the matrix, WPATH.

A heading CUMULATIVE ABSORBER AMOUNTS FOR THE ATMOSPHERIC PATH is then printed followed by 12 columns. The first column gives an integer associated with the layer traversal by the atmospheric slant path. The following 10 columns which give the cumulative absorber amounts for the following species: water vapor, uniformly mixed gases, ozone, nitrogen continuum, water vapor continuum (10 μm), molecular scattering, aerosol extinction, UV ozone, water vapor continuum (4 μm) and nitric acid. The last column is the average temperature of the layer.

A radiance table, containing six columns, now follows. The first two columns give the frequency (cm^{-1}) and the wavelength (μm). The next two columns give the radiance in units of W/cm^2-ster-cm^{-1} and W/cm^2-ster-μm. The next column gives the cumulative integrated radiance (W/cm^2-ster). The last column is the total transmittance.

Finally the maximum and minimum radiances and their frequencies, the integrated absorption, the average transmittance, and the total integrated radiance are printed.

8. EXAMPLES OF RADIANCE SPECTRA

Some examples of radiance spectra obtained from LOWTRAN 4 are presented in Figures 3 through 9. Figures 3 and 4 show the atmospheric radiance as seen by an observer at the ground looking straight up to space (H1=0 km, zenith ANGLE=0°) for the six model atmospheres with a 23 km visual range. Figure 3 is for the spectral region from 400 to 2000 cm^{-1} a Figure 4 for the spectral region from 2000 to 3600 cm^{-1}.

Figures 5 and 6 show the atmospheric radiance as seen by an observer in space looking straight down to the ground (H1= 100 km, zenith ANGL =180°) for the six model atmospheres with a 23 km visual range. The temperature of the ground for these plots is the appropriate boundary temperature of the first layer in the model atmosphere. Figure 5 is for the spectral region from 400 to 2000 cm^{-1} and Figure 6 for the spectral region from 2000 to 3600 cm^{-1}.

Figures 7 through 9 show atmospheric radiance spectra from 400 to 4000 cm^{-1} calculated using the U.S. Standard Atmosphere, 1962, with a 23 km visual range for three different types of atmospheric paths. Figure 7 shows the zenith radiance for an observer at altitudes of 0, 20, and 40 km. Figure 8 shows the atmospheric

radiance at a zenith angle of 45° as seen by an observer at altitudes of 0, 20, and 40 km. Figure 9 shows the comparisons of the limb radiance as seen from space for tangent heights of 0, 20, and 40 km.

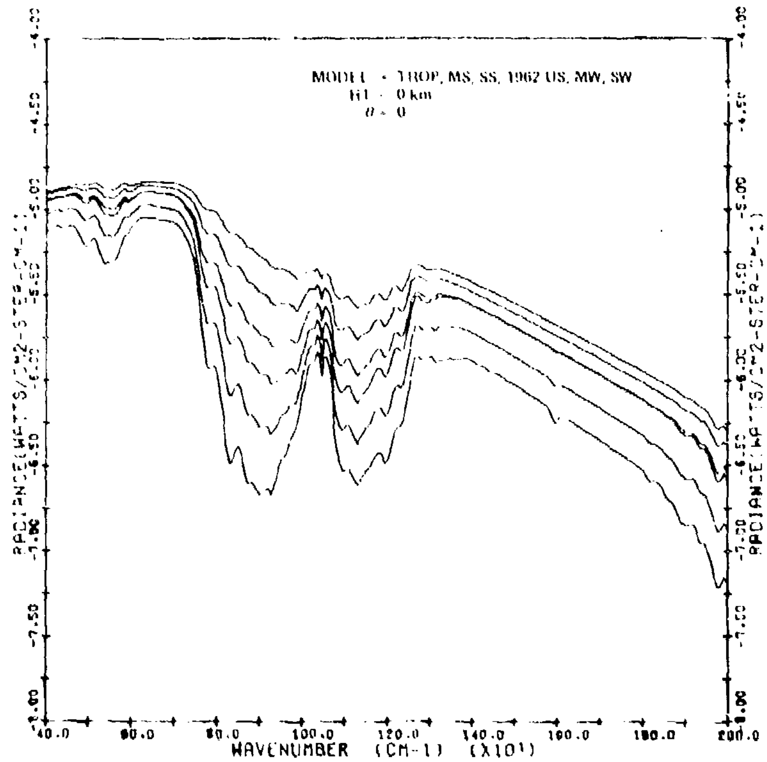

Figure 3. Atmospheric Radiance for a Vertical Path to Space from Ground Level for Six Model Atmospheres (400 to 2000 cm^{-1})

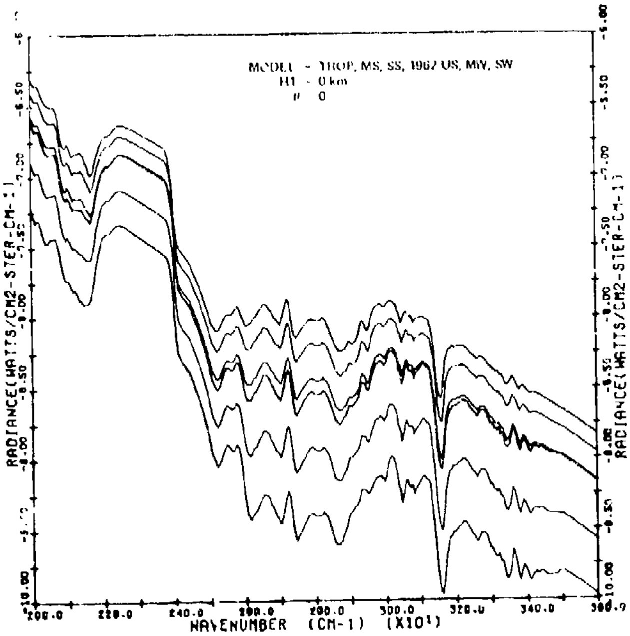

Figure 4. Atmospheric Radiance for a Vertical Path to Space from Ground Level for Six Model Atmospheres (2000 to 3600 cm^{-1})

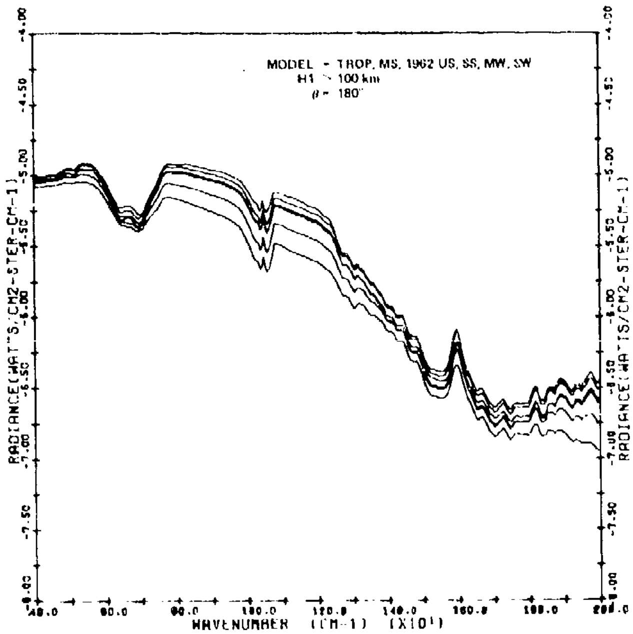

Figure 5. Atmospheric Radiance for a Vertical Path to Ground from Space for Six Model Atmospheres (400 to 2000 cm^{-1})

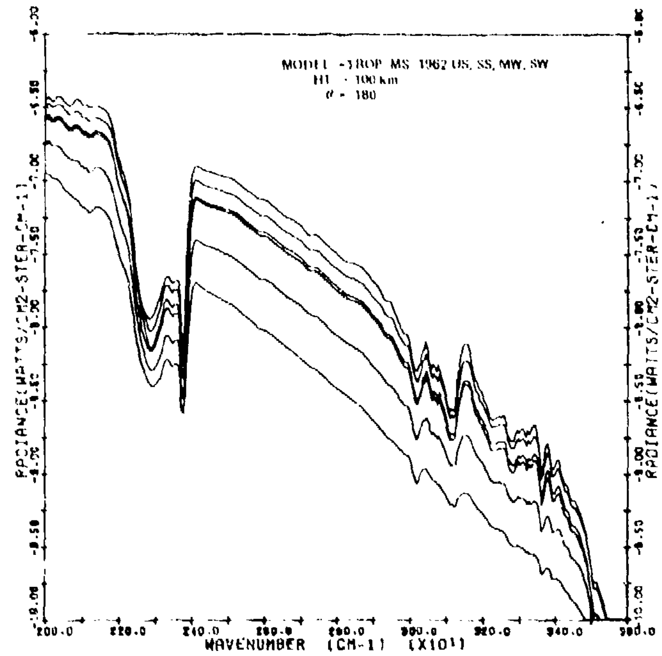

Figure 6. Atmospheric Radiance for a Vertical Path to Ground from Space for Six Model Atmospheres (2000 to 3600 cm^{-1})

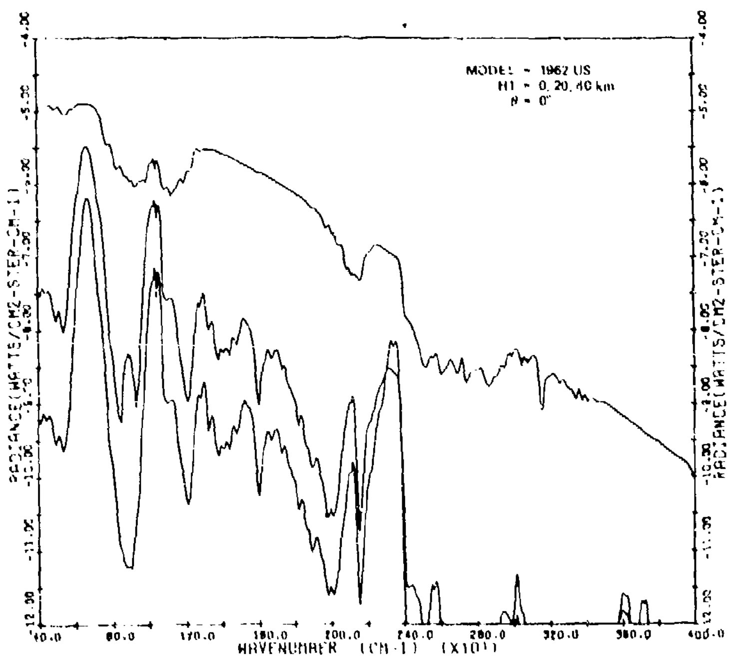

Figure 7. Variation of Atmospheric Radiance With Altitude for Vertical Paths to Space and the 1962 U.S. Standard Atmosphere

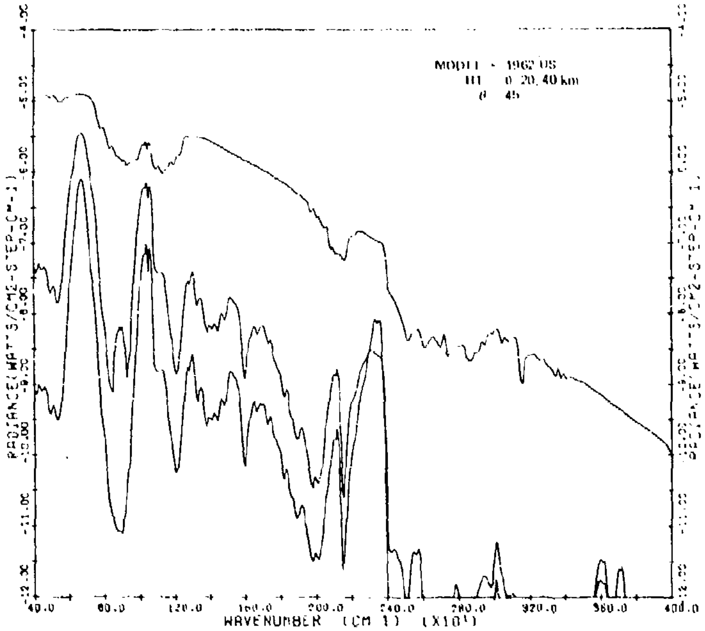

Figure 8. Variation of Atmospheric Radiance With Altitude for Slant Paths to Space (Zenith Angle = 45°) and the 1962 U.S. Standard Atmosphere

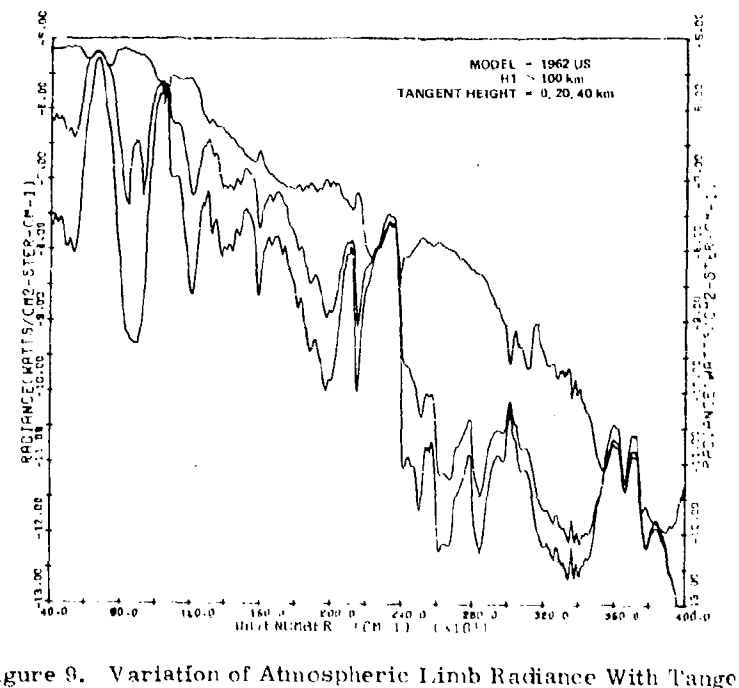

Figure 9. Variation of Atmospheric Limb Radiance With Tangent Height for the 1962 U.S. Standard Atmosphere

9. COMPARISONS WITH MEASUREMENTS

Figures 10 through 22 show some comparisons of LOWTRAN 4 calculations with measurements of atmospheric spectral radiance from both balloon and satellite platforms.

Figure 10 shows a comparison of the calculated upward atmospheric radiance with an interferometer measurement from a balloon flight over northern Nebraska by Chaney at the University of Michigan.[9] The measurement was taken at a float altitude of 111,700 ft. The calculated radiance used the midlatitude winter model, with a 23 km visual range, and a ground temperature of 280°K.

Figure 11 shows a comparison of an interferometer measurement made from the Nimbus 3 satellite[10] looking down over the Gulf of Mexico with the calculated atmospheric radiance. The resolution of the interferometer was 5 cm^{-1} as compared to the 20 cm^{-1} resolution of LOWTRAN. Two theoretical models, the tropical and midlatitude summer, were used for comparison, as shown in Figure 11, and are displaced two divisions above and below the measured radiance for clarity. Both models assumed a 23 km visual range and used the temperature at OKM in the model atmosphere as the boundary temperature.

Figure 12 shows the comparison of atmospheric radiance as seen from space between the LOWTRAN calculation and measurements from the Nimbus 4 satellite[11] for three different geographic locations. The spectra, obtained with a Michelson interferometer of resolution 2.8 cm^{-1}, were measured over the Sahara Desert, the Mediterranean, and the Antarctic. The calculated LOWTRAN radiances used the midlatitude winter model and a ground temperature of 320°K for the Sahara; the midlatitude winter model and a ground temperature of 285°K for the Mediterranean; and an arctic winter cold model taken from the AFCRL Handbook of Geophysics and Space Environments[12] and a ground temperature of 190°K for the Antarctic comparison. All three calculations assumed a 23 km visual range for aerosols.

Figures 13 through 22 show a detailed comparison of calculated and observed atmospheric spectral radiance vs wavelength in both the 8 to 14 μm and the 18 to 27 μm spectral regions. The measurements were made on a balloon flight launched

9. Chaney, L.W. (1969) An Experimental Fourier Transform Asymmetrical Interferometer for Atmospheric Radiation Measurements, University of Michigan Technical Report 05863-18-T.

10. Conrath, B.J., Hanel, R.A., Kunde, V.G., and Prabhakara, C. (1970) The Infrared Interferometer Experiment on Nimbus 3, Goddard Space Flight Center Greenbelt, Maryland, Report X-620-70-213.

11. Hanel, R.A., and Conrath, B.J. (1970) Thermal Emission Spectra of the Earth and Atmosphere Obtained from the Nimbus 4 Michelson Interferometer Experiment, Goddard Space Flight Center, Greenbelt, Maryland, Report X-620-70-244.

12. Valley, S.D., Ed. (1965) Handbook of Geophysics and Space Environments, AFCRL.

from Holloman AFB, New Mexico by Murcray et al,[13] University of Denver. The instrument used for these observations was a LHe grating spectrometer, operated in the first and second order of the grating. The resolution was 0.03 μm in the 8 to 14 μm region, and 0.06 μm in the 18 to 27 μm region. The data in these figures are presented as a function of altitude and as a function of zenith angle. Figures 13 through 18 cover the 8 to 14 μm region and Figures 19 through 22, the 18 to 27 μm region. The LOWTRAN radiance calculation used the pressure, temperature, ozone, and nitric acid profiles from the Murcray report,[13] and the midlatitude winter water vapor profile contained in LOWTRAN.

The dominant spectral features in Figures 13 to 18 are the 9.0 and 9.6 μm ozone bands, the 11.3 μm band of nitric acid, and the carbon dioxide bands between 12 and 14 μm. In the long wavelength region, the spectral radiance is due primarily to water vapor rotational transitions. Because the resolution of the LOWTRAN radiance calculation is inferior to the measurements in this region, the comparisons here can only serve to verify the level of the calculated radiance.

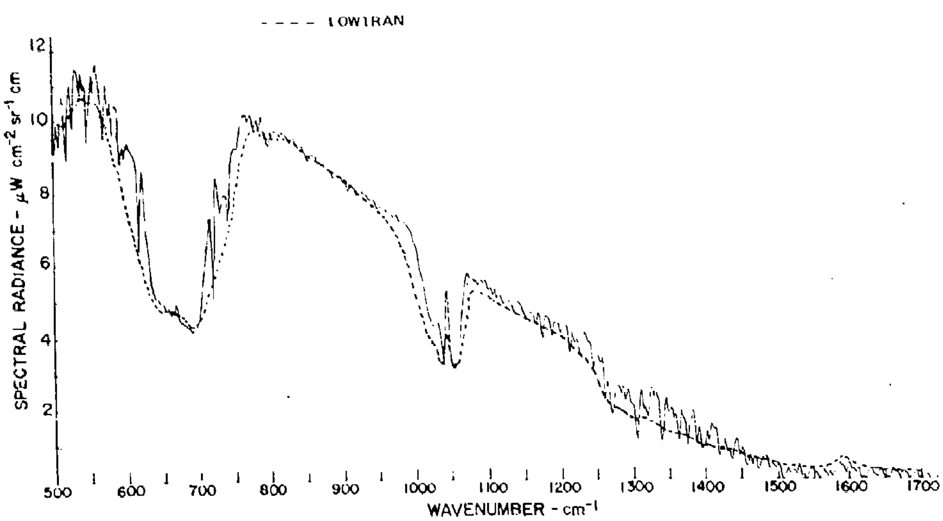

Figure 10. Comparison Between LOWTRAN Prediction and University of Michigan Balloon Measurement of Atmospheric Radiance Over Northern Nebraska

13. Murcray, D.G., Brooks, J.N., Goldman, A., Kosters, J.J., and Williams, W.J. (1977) Water Vapor Nitric Acid and Ozone Mixing Ratio Height Profiles Derived from Spectral Radiometric Measurements, University of Denver, Denver, Colorado 80208, Contract Report No. 332.

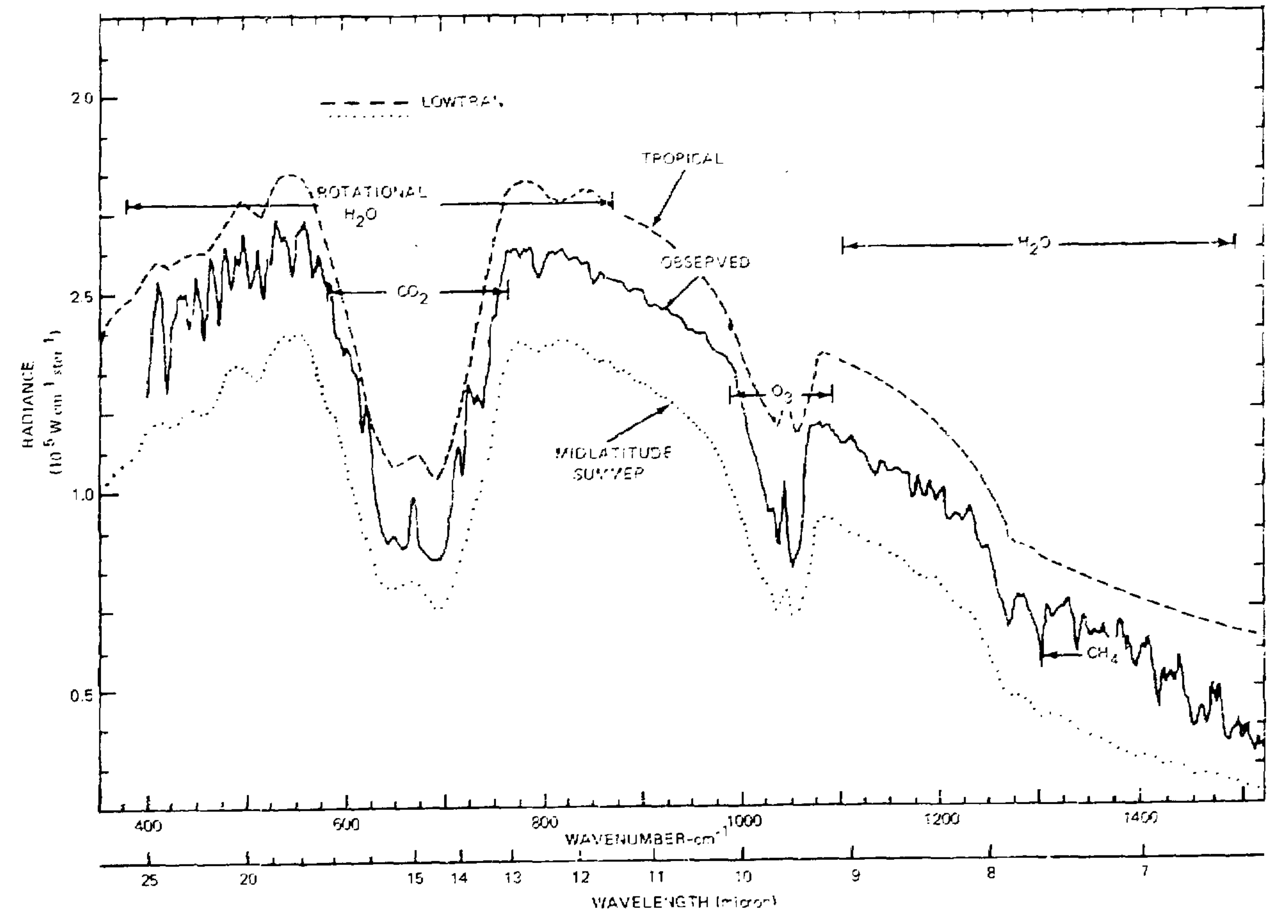

Figure 11. Comparison Between LOWTRAN Prediction and NIMBUS 3 Satellite Measurement of Atmospheric Radiance Over the Gulf of Mexico

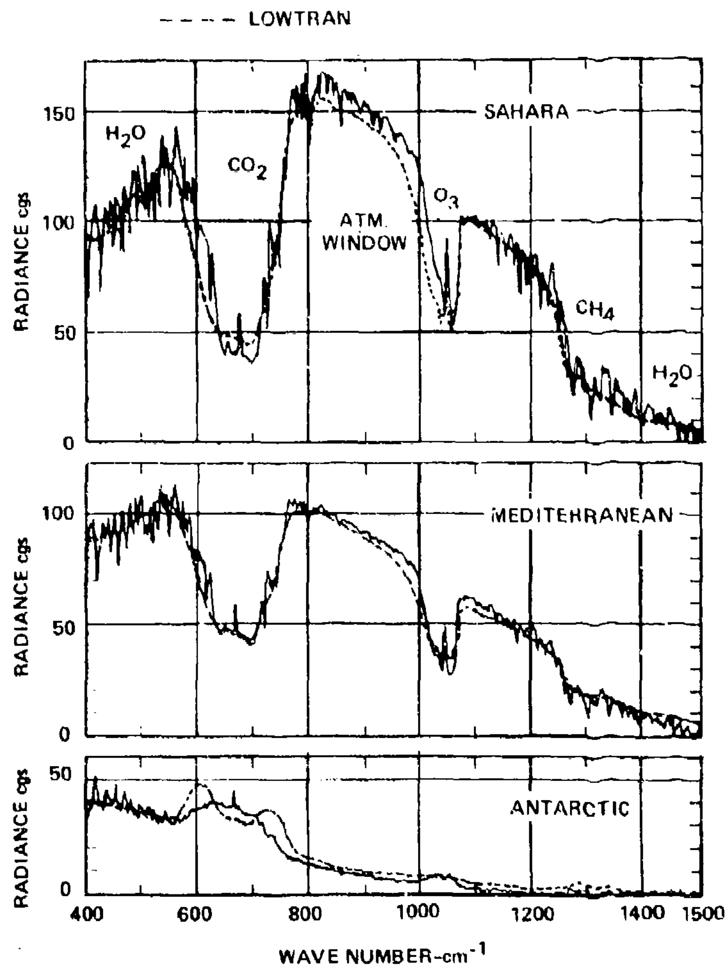

Figure 12. Comparison Between LOWTRAN Prediction and NIMBUS 4 Satellite Measurements of Atmospheric Radiance over the Sahara Desert, the Mediterranean, and the Antarctic

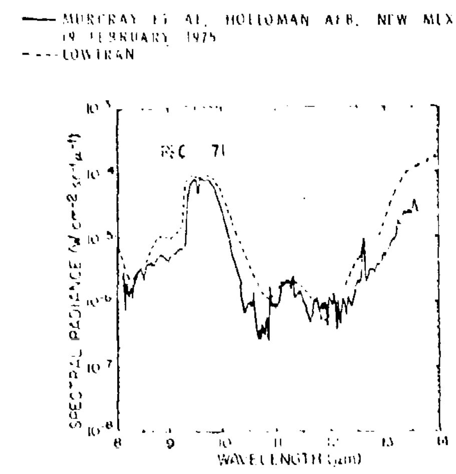

Figure 13. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

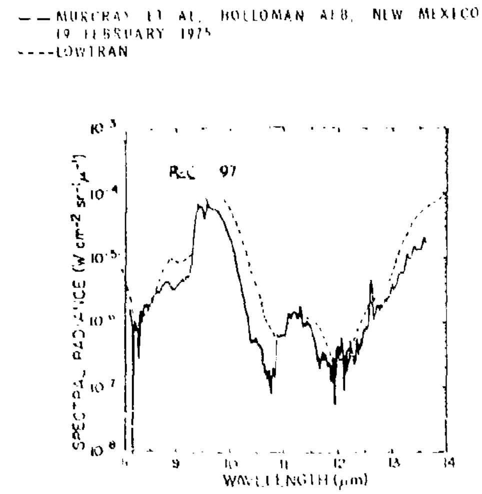

Figure 14. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 13.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

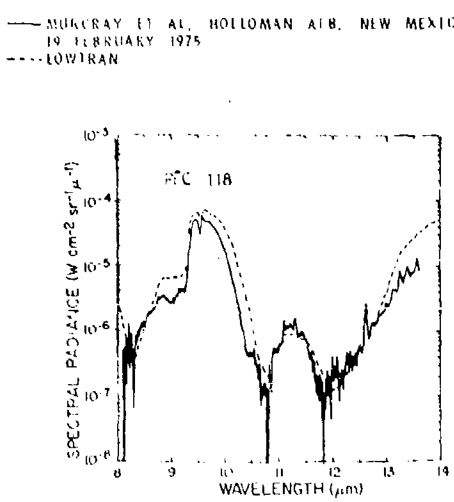

Figure 15. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 18.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

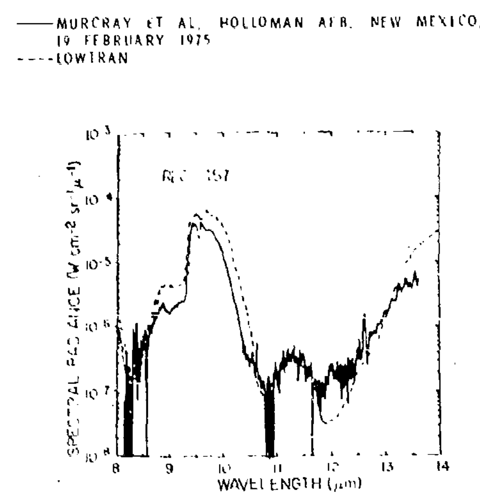

Figure 16. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 24.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

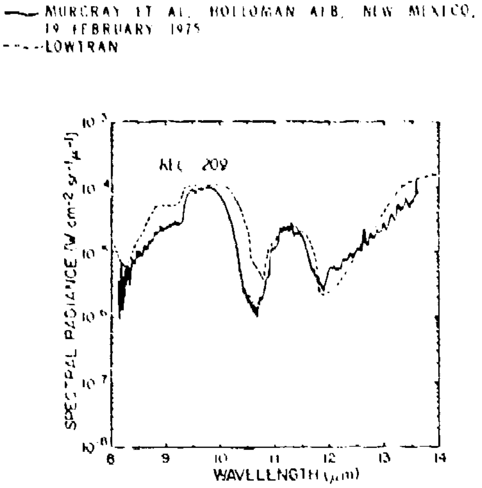

Figure 17. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 93° on 19 February 1975, and LOWTRAN Comparison

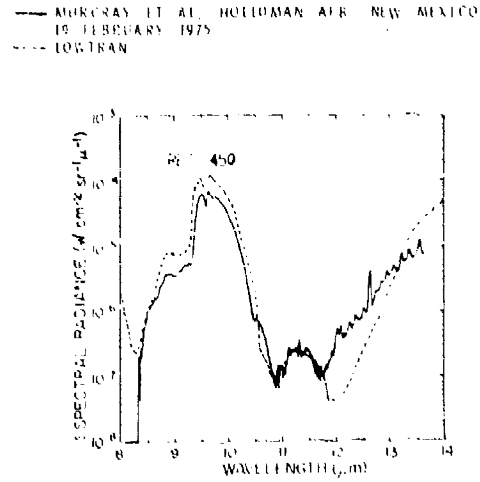

Figure 18. Sample Spectrum of Short Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 81° on 19 February 1975, and LOWTRAN Comparison

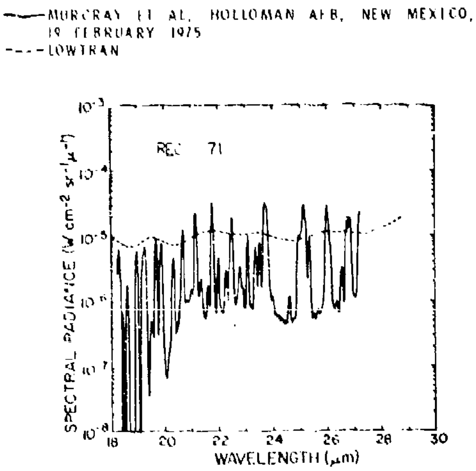

Figure 19. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 9.5 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

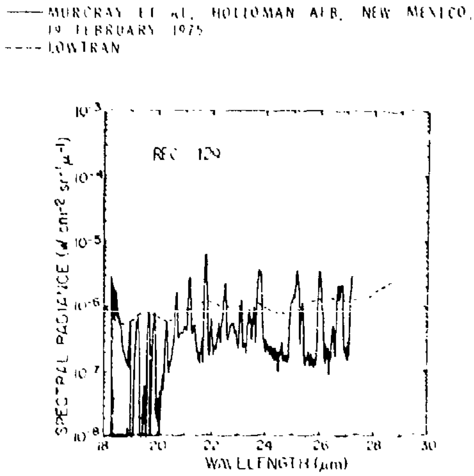

Figure 20. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 20.0 km and a Zenith Angle of 63° on 19 February 1975, and LOWTRAN Comparison

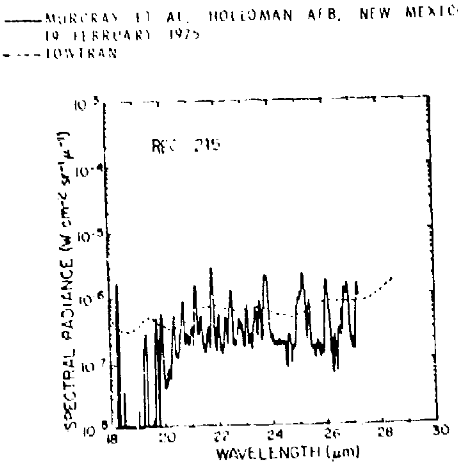

Figure 22. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 81° on 19 February 1975, and LOWTRAN Comparison

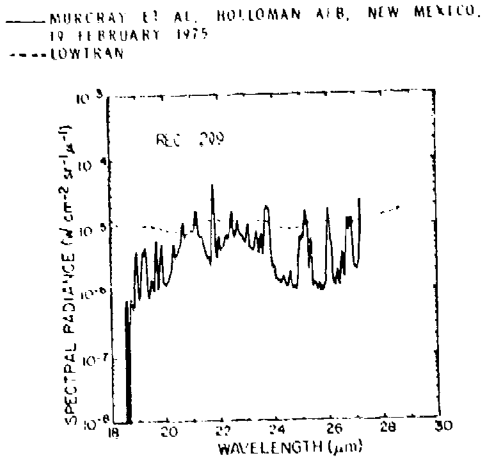

Figure 21. Sample Spectrum of Long Wavelength Region Observed at an Altitude of 29.1 km and a Zenith Angle of 93° on 19 February 1975, and LOWTRAN Comparison

10. COMMENTS

The LOWTRAN model was originally conceived as an atmospheric transmittance model. In the conversion to a radiance model, additional constraints on both the validity of the model as well as the range of applicability are introduced for atmospheric radiance calculations. It should be remembered that the digitized molecular absorption coefficients in LOWTRAN were obtained for conditions representstive of moderate atmospheric paths and will tend to underestimate the transmittance for very long paths and overestimate the transmittance for very short paths. The modification of the transmittance function described in Section 3 was made to give some improvements to the radiance calculations for the short path cases. In addition, the radiance calculations assume local thermodynamic equilibrium exists in each layer of the model atmospheres. This assumption will break down for radiance calculations in the upper atmosphere. Therefore, because of the limitations in the LOWTRAN model for short paths (or small absorber amounts) and deviations from thermal equilibrium, both conditions which occur in the upper atmosphere it is recommended that the LOWTRAN radiance calculations be restricted to altitudes below 40 km.

For the shorter wavelengths (< 5 μm), scattered solar radiation becomes an important source of background radiation. Since this has not been included in the LOWTRAN model, radiance calculations at the shorter wavelengths with a sunlit atmosphere should be made with caution.

With the obvious limitations in the LOWTRAN radiance code described above, the agreement between measurements and radiance calculations shown in Figures 10 through 22 is remarkably good for the cases considered. Further comparisons with measurements are planned for other spectral regions and other geometries to verify the radiance model.

An additional note should be made here on the calculation of transmittance. Although the code will calculate total transmittance for a given atmospheric path in either mode of program execution, the time is increased by a factor of N in the radiance mode, where N is the number of atmospheric layers along a given path.

References

1. Selby, J.F.A., Shettle, E.P., and McClatchey, R.A. (1976) Atmospheric Transmittance from 0.25 to 28.5 μm: Supplement LOWTRAN 3B, AFGL-TR-76-0258.

2. Selby, J.F.A., and McClatchey, R.A. (1975) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 3, AFCRL-TR-75-0255.

3. Selby, J.F.A., and McClatchey, R.A. (1972) Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN 2, AFCRL-TR-72-0745.

4. Manley, O.P., Smith, H.J.P., Treve, Y.M., Carpenter, J.W., Degges, T.C., and Doan, L.R. (1971) OPTIR II, AFCRL-71-0528 (Vol. 2 & 3); (1973) OPTIR III, AFCRL-TR-73-0217 and 0491; and (1974) OPTIR IIIB, AFCRL-TR-74-0319.

5. McClatchey, R.A., Fenn, R.W., Selby, J.E.A., Volz, F.E., and Garing, J.S. (1972) Optical Properties of the Atmosphere (Third Edition) AFCRL-72-0497.

6. Murcray, D.G., Kyle, T.G., Murcray, F.H., and Williams, W.G. (1968) Nitric acid and nitric oxide in the lower stratosphere. Nature 218:78.

7. Goldman, A., Kyle, T.G., and Bonomo, F.W. (1971) Statistical band model parameters and integrated intensities for the 5.9-μ, 7.5-μ, and 11.3-μ bands of HNO_3 vapor, Appl. Opt. 1:65.

8. Evans, W.F., Kerr, J.B., and Wardle, D.I. (1975) The AES Stratospheric Balloon Measurements Project: Preliminary Results, Atmospheric Environment Service, Downsview, Ontario, Canada, Report No. APRB 30 X 4.

9. Chaney, L.W. (1969) An Experimental Fourier Transform Asymmetrical Interferometer for Atmospheric Radiation Measurements, University of Michigan Technical Report 05863-18-T.

10. Conrath, B.J., Hanel, R.A., Kunde, V.G., and Prabhakara, C. (1970) The Infrared Interferometer Experiment on Nimbus 3, Goddard Space Flight Center Greenbelt, Maryland, Report X-620-70-213.

11. Hanel, R.A., and Conrath, B.J. (1970) Thermal Emission Spectra of the Earth and Atmosphere Obtained from the Nimbus 4 Michelson Interferometer Experiment, Goddard Space Flight Center, Greenbelt, Maryland, Report X-620-70-244.

12. Valley, S.L., Ed. (1965) Handbook of Geophysics and Space Environments, AFCRL.

13. Murcray, D.G., Brooks, J.N., Goldman, A., Kosters, J.J., and Williams, W.J. (1977) Water Vapor, Nitric Acid and Ozone Mixing Ratio Height Profiles Derived from Spectral Radiometric Measurements, University of Denver, Denver, Colorado 80208, Contract Report No. 332.

Appendix A

Listing of Program and Data

A listing of the Fortran program LOWTRAN 4 (PROGRAM LOWEM) is given in Table A1 together with the four subroutines PATH, HNO3, POINT, and ANGL. The input data for the program is given in Table A2. A general flow chart for the main program is presented in Appendix B, and definitions of the symbols used in the computer codes are summarized in Appendix C.

The subroutine POINT has a twofold purpose. When the subroutine is called for a given altitude X, it is used to determine the mean refractive index (1) and in the layer between X and the level above, TX(9), and (2) in the layer between X and the level below, XN. In addition, an interpolation scheme is used to determine the effective absorber amounts per km at altitude X for each absorber. When the parameter IP is set equal to zero, only the mean refractive index above and below altitude X is determined from POINT.

The subroutine ANGL is used solely for the purpose of calculating the initial zenith angle (θ_0 or ANGLE) by an iterative scheme taking into account refraction, given (1) the initial and final altitudes of the path (H1 and H2 respectively) and the angle subtended at the earth's center (β or BETA) by the trajectory, or (2) the initial altitude and tangent height (H1 and HMIN respectively). A more detailed explanation of subroutine ANGL is given in Appendix C of the LOWTRAN 3 report.[2]

PATH and HNO3 are new subroutines which have been added to the program. Subroutine PATH is used to determine and store the cumulative absorber amounts through the layers of the atmospheric slant path. Subroutine HNO3 is called to find the nitric acid absorption coefficients as a function of frequency.

The last column in the listing of the program in Table A1 is the corresponding listing of the LOWTRAN 3B computer code. Changes in the previous code are indicated by the word, NEW.

It should be noted that in the main program, card LOWE 7390, the temporary fog correction has been commented. The fog model should only be used for transmittance calculations as discussed in Appendix D. It should not be used for radiance calculations.

Table A1. Listing of Fortran Code LOWTRAN 4

```
      PROGRAM LOWTRN(INPUT,OUTPUT,TAPE5,TAPE6=OUTPUT,TAPE7)
      COMMON Z(34),P(7,34),T(7,34),FH(11,34),WH(7,34),M,NL,RE,CH,CO,PI
      DIMENSION WO(7,34),HZ1(34),HZ2(6),AHAZE(34),AHZ2(70)
      DIMENSION TR(67),FW(67),FO(67),HZ(2),TX(11),VH(11)
      DIMENSION HSTOR(34)
      COMMON C1(2580),C2(1575),C3(540),C4(133),C5(15),C8(102)
      COMMON     VX(45),C7(45),C7A(45)
      DIMENSION HMIX(34),WLAY(34,11)
       DIMENSION WPATH(68,11),TBBY(68)
      COMMON /EMI/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE
      COMMON /EM2/ IL,IKMAX  ,LENSTOR ,NLL,R(11),E(11)
      COMMON /EM3/ H1,H2,NP1 ,MODEL
C HMIX(I)=HNO3 VOLUME MIXING RATIOS TIMES E+09 FROM EVANS PROFILE
      DATA HMIX/9*0.,0.1,0.33,0.8,1.2,1.4,1.6,1.8,1.9,2.0,2.1,2.3,3.0,3.
     17,4.2,5.2,6.0,3.8,2.6,0.22,6*0.0/
      FE(T,V)=1.19096E-16*(V**5)/(EXP(1.43879*V/T)-1.)
C        WATTS, CM-2 ST-1 MICRON-1
      F(A)=EXP(18.9766-14.9595*A-2.43882*A*A)*A
      DATA HZ(1)/5H23 KM/,HZ(2)/5H 5 KM/
C*****************************************************************
C     LOWTRAN      1 DEC 77
C
*                AUTHORS
*                J.E.A. SELBY,
*                F.X.KNEIZYS,
*                J. H. CHETWYND JR.
*                R. A. MCCLATCHEY
C
C     PROGRAM LOWTRAN  CALCULATES THE TRANSMITTANCE    AND/OR RADIANCE
C     OF THE ATMOSPHERE
C     FROM 350 CM-1 TO 40000 CM-1 (0.25 TO 28.57 MICRONS) AT 20 CM-1
C     SPECTRAL RESOLUTION ON A LINEAR WAVENUMBER SCALE.
C     REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED.    ATMOSPHERE
C     IS LAYERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. INTER-
C     VALS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.
C     INTERVAL TO 100 KM.
C*****************************************************************
C     PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS
C
C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND
C                                            FORMAT(11I3,2F10.3)
C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS                  FORMAT(7F10.3)
C   CARD 3 V1, V2, DV                                  FORMAT(7F10.3)
C   CARD 4 IXY                                         FORMAT(I3)
C
C     MODEL=1,2,3,4,5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE
C     TROPICAL,MIDLATITUDE SUMMER,MIDLATITUDE WINTER,SUBARCTIC SUMMER,
C     SUBARCTIC WINTER,OR THE 1962 U.S.  STANDARD RESPECTIVELY
C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED(INSTEAD OF CARD 2
C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSIT
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
C       (GM.M-3),O3 DENSITY(GM.M-3) , VIS(KM),RANGE(KM) WITH FORMAT 429.  LOWE 510     A   28*
C       MODEL=7 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.     LOWE 520     A   29A
C       DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN! LOWE 530     A   29B
C       ALTITUDE(KM.),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY,LOWE 540     A   29C
C       O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.     LOWE 550     A   29D
C       NOTE THAT EITHER DEW PT, TEMP,OR REL. HUMIDITY CAN BE USED.       LOWE 560     A   29E
C                                                                         LOWE 570     A   29F
C       M1,M2,M3, ARE USED TO CHANGE TEMP,H2O, AND O3 ALTITUDE PROFILES.  LOWE 580     A   29G
C          IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE            LOWE 590        NEW
C          TBOUND=TEMPERATURE OF EARTH IN DEGREES KELVIN                  LOWE 600        NEW
C          IF TBOUND = ZERO, ASSUMES AIR TEMPERATURE OF MODEL ATMOS.      LOWE 610        NEW
C                                                                         LOWE 620     A   30
C       IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED                      LOWE 630     A   31
C       IHAZE =1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN         LOWE 640     A   32
C       CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))                        LOWE 650     A   33
C       IHAZE = 1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS.LOWE 660     A   34
C       HAZE MODELS RESPECTIVELY IF VIS =0 ON CARD 2                      LOWE 670     A   35
C       IHAZE = 7 FOR OTHER AEROSOL MODELS (E.G. MARITIME ECT) WHICH      LOWE 680     A   35+
C       ARE READ INTO PROGRAM                                             LOWE 690     A   35+
C                                                                         LOWE 700     A   36
C       ITYPE=1,2  OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH            LOWE 710     A   37
C       ITYPE=3,VERTICAL OR SLANT PATH TO SPACE                           LOWE 720     A   38
C       ITYPE=2,VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES              LOWE 730     A   39
C       ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH     LOWE 740     A   40
C                                                                         LOWE 750     A   41
C       H1=OBSERVER ALTITUDE (KM)                                         LOWE 760     A   42
C       H2=SOURCE  ALTITUDE (KM)                                          LOWE 770     A   43
C       ANGLE= ZENITH ANGLE AT H1 (DEGREES)                               LOWE 780     A   44
C       RANGE=PATH LENGTH (KM)                                            LOWE 790     A   45
C       BETA=EARTH CENTRE ANGLE                                           LOWE 800     A   46
C       VIS = VISUAL RANGE AT SEA LEVEL (KM)                              LOWE 810     A   47
C       (IF ITYPE=1 READ H1 AND RANGE;IF ITYPE=3 READ H1 AND ANGLE.       LOWE 820     A   48
C       IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)    LOWE 830     A   49
C                                                                         LOWE 840     A   50
C       V1=INITIAL FREQUENCY (WAVENUMBER CM-1 ) INTEGER VALUE             LOWE 850     A   51
C       V2=FINAL FREQUENCY(WAVENUMBER CM-1 ) INTEGER VALUE                LOWE 860     A   52
C       DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED         LOWE 870     A   53
C       NOTE! DV MUST BE A MULTIPLE OF 5 CM-1                             LOWE 880     A   54
C                                                                         LOWE 890     A   55
C       IXY=0  TO END DATA ,=1 FOR NEW V1,V2,DV ONLY , =2 TO CONTINUE DATALOWE 900     A   56
C       IXY=3 FOR NEW CARD 2 ONLY,=4 FOR NEW CARD 1 ONLY.                 LOWE 910     A   57A
C*************************************************************************LOWE 920     A   57B
        HMIX(9)=HMIX(29)=1.0 E-50                                         LOWE 930        NEW
        IXY=0                                                             LOWE 940     A   57C
        KMAX=11                                                           LOWE 950        NEW
        READ (5,400) IATM,NL                                              LOWE 960     A   58
        READ (5,401) (HZ1(I),I=1,NL)                                      LOWE 970     A   59
        READ (5,401) (HZ2(I),I=1,5)                                       LOWE 980     A   60
        HZ2(6)=HZ1(6)                                                     LOWE 990     A   60+
        DO 1 J=1,3                                                        LOWE1000     A   61
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      K2=2*J                                                            LOWE1010   A  62
      K1=K2-1                                                           LOWE1020   A  63
      DO 1 I=1,NL                                                       LOWE1030   A  64
1     READ (5,402) Z(I),(P(K,I),T(K,I),WH(K,I),WO(K,I),K=K1,K2)         LOWE1040   A  65
      READ (5,431) (VX(I),C7(I),C7A(I),I=1,44)                          LOWE1050   A  66*
      READ (5,403) (TP(I),FH(I),FO(I),I=1,67)                           LOWE1060   A  67
      READ (5,404) (C1(I),I=1,2580)                                     LOWE1070   A  68
      READ (5,404) (C2(I),I=1,1575)                                     LOWE1080   A  69
      READ (5,404) (C3(I),I=1,540)                                      LOWE1090   A  70
      READ (5,405) (C4(I),I=1,133)                                      LOWE1100   A  71
      READ (5,404) (C5(I),I=1,15)                                       LOWE1110   A  72
      READ (5,405) (C8(I),I=1,102)                                      LOWE1120   A  73

      JSTOR=0                                                           LOWE1140     NEW
      PI=2.0*ASIN(1.0)                                                  LOWE1150   A  74*
      CA=PI/180.                                                        LOWE1160   A  75
      IP=0                                                              LOWE1170   A  76
2     CONTINUE                                                          LOWE1180   A  77
      RE=6371.23                                                        LOWE1190   A  78
      IFIND=0                                                           LOWE1200   A  79
C     JP NE 0  SUPPRESS PRINT                                           LOWE1210   A  79+
      READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE1220     NEW
C  IEMISS=0=TRANSMISSION MODE / IEMISS=1=EMISSION MODE                  LOWE1230     NEW
      IF(IEMISS.EQ.1) PRINT 1170                                        LOWE1240     NEW
      IF(IEMISS.EQ.0) PRINT 1171                                        LOWE1250     NEW
      LENSTOR=LEN                                                       LOWE1260     NEW
      PRINT400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE1270     NEW
200   M=MODEL                                                           LOWE1280   A  82
      IF (M.EQ.1) RE=6378.39                                            LOWE1290   A  83
      IF (M.EQ.4) RE=6356.91                                            LOWE1300   A  84
      IF (M.EQ.5) RE=6356.91                                            LOWE1310   A  85A
       IF(IHAZE.NE.7) GO TO 250                                         LOWE1320   A  85B
      READ 431,(VX(I),C7(I),C7A(I),I=1,44)                              LOWE1330   A  85C
      PRINT 431,(VX(I),C7(I),C7A(I),I=1,44)                             LOWE1340   A  85D
      IHAZE=1                                                           LOWE1350   A  85
250   IF(RO.GT.0)RE=RO                                                  LOWE1360   A  [illegible]
      IF(M.EQ.7.AND.IM.NE.0) GO TO 4                                    LOWE1370   A  [illegible]
      IF(IXY.GT.3) GO TO 8                                              LOWE1380   A  [illegible]
      IF (MODEL.EQ.0) GO TO 4                                           LOWE1390   A  86
300   READ 406, H1,H2,ANGLE,RANGE,BETA,VIS                              LOWE1400   A  87*
      PRINT 425, H1,H2,ANGLE,RANGE,BETA,VIS                             LOWE1410   A  88
      X1=RE+H1                                                          LOWE1420   A  89
      IF (ITYPE.EQ.3) GO TO 560                                         LOWE1430   A  90*
      IF (ITYPE.EQ.1) GO TO 8                                           LOWE1440   A  91
      X2=RE+H2                                                          LOWE1450   A  92
      IF (RANGE.EQ.0.) GO TO 5                                          LOWE1460   A  93
      PRINT 428, H1,H2,ANGLE,RANGE,BETA,VIS                             LOWE1470   A  94
      IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3                               LOWE1480   A  95
      ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA            LOWE1490   A  96
      GO TO 7                                                           LOWE1500   A  97
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
3     X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)        LOWE1510   A  98
      H2=X2-RE                                                         LOWE1520   A  99
      GO TO 7                                                          LOWE1530   A 100
4     CONTINUE                                                         LOWE1540   A 101*
      IF(ML.LE.0)ML=1                                                  LOWE1550   A 102*
      DO 540 K=1,ML                                                    LOWE1560   A 103A
      AHAZE(K)=0.0                                                     LOWE1570   A 103B
      IF(M.EQ.0)READ 429,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE LOWE1580   A 103C
      IF(M.EQ.0)PRINT 430,H1,P(7,1),TMP,DP,RH,WH(7,K),WO(7,K),VIS,RANGE LOWE1590  A 103D
      IF(M.GT.0)READ 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K) LOWE1600  A 103E
      IF(M.EQ.0)Z(K)=H1                                                LOWE1610   A*103F
      J=IFIX(Z(K)+1.0E-6)+1.                                           LOWE1620   A*103G
      IF(Z(K).GE.25.0) J=(Z(K)-25.0)/5.0+26.                           LOWE1630   A 103H
      IF(Z(K).GE.50.0) J=(Z(K)-50.0)/20.0+31.                          LOWE1640   A 103I
      IF(Z(K).GE.70.0) J=(Z(K)-70.0)/30.0+32.                          LOWE1650   A 103J
      IF(J.GT.33)J=33                                                  LOWE1660   A 103K
      FAC=Z(K)-FLOAT(J-1)                                              LOWE1670   A 103L
      IF(J.LT.26) GO TO 500                                            LOWE1680   A 103M
      FAC=(Z(K)-5.0*FLOAT(J-26)-25.)/5.                                LOWE1690   A 103N
      IF(J.GE.31) FAC=(Z(K)-50.0)/20.                                  LOWE1700   A 103O
      IF(J.GE.32) FAC=(Z(K)-70.0)/30.                                  LOWE1710   A 103P
      IF(FAC.GT.1.0) FAC=1.0                                           LOWE1720   A 103Q
500   L=J+1                                                            LOWE1730   A 103R
      T(7,K)=TMP+273.15                                                LOWE1740   A 103S
      IF(M1.GT.0)T(7,K)=T(M1,J)*(T(M1,L)/T(M1,J))**FAC                 LOWE1750   A 103T
      TT=273.15/T(7,K)                                                 LOWE1760   A 103U
      IF(RH.LE.0.0) TT=273.15/(273.15+DP)                              LOWE1770   A 103V
      IF(WH(7,K).LE.0.0) WH(7,K)=F(TT)                                 LOWE1780   A 103W
      IF(M2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,L)/WH(M2,J))**FAC             LOWE1790   A 103X
      IF(RH.GT.0.0) WH(7,K)=0.01*RH*WH(7,K)                            LOWE1800   A 103Y
      IF(M3.GT.0)WO(7,K)=WO(M3,J)*(WO(M3,L)/WO(M3,J))**FAC             LOWE1810   A 103Z
       HSTOR(K)=0.                                                     LOWE1820     NEW
      IF(HMIX(J).LE.0.) GO TO 522                                      LOWE1830     NEW
        HSTOR(K)=HMIX(J)*(HMIX(L)/HMIX(J))**FAC                        LOWE1840     NEW
 522   CONTINUE                                                        LOWE1850     NEW
      IF(Z(K).GE.5.0)GO TO 520                                         LOWE1860   A 104A
      IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ2(J)*(HZ2(L)/HZ2(J))**FAC          LOWE1870   A 104B
520   IF(AHAZE(K).EQ.0.0)AHAZE(K)=HZ1(J)*(HZ1(L)/HZ1(J))**FAC          LOWE1880   A 104C
      IF(MODEL.EQ.0)GO TO 8                                            LOWE1890   A 104D
      IF(K.EQ.1)PRINT 441                                              LOWE1900   A 104E
      PRINT 429,Z(K),P(7,K),TMP,DP,RH,WH(7,K),WO(7,K),AHAZE(K)         LOWE1910   A 104F
540   CONTINUE                                                         LOWE1920   A 104G
      IM=0                                                             LOWE1930   A 104H
      NL=ML                                                            LOWE1940   A 104I
      M1=0                                                             LOWE1950   A 104J
      M2=0                                                             LOWE1960   A 104K
      M3=0                                                             LOWE1970   A 104L
C     NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARDLOWE1980  A 104M
C     MODEL ATMOSPHERES                                                LOWE1990   A 104N
      IF(IXY.GT.3) GO TO 8                                             LOWE2000     NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      GO TO 300                                                     LOWE2010    A 104O
560   IF (RANGE.GT.0.0) GO TO 580                                   LOWE2020    A 104P
      IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1                           LOWE2030    A 104Q
      GO TO 8                                                       LOWE2040    A 104R
580   ITYPE=2                                                       LOWE2050    A 104S
      BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA           LOWE2060    A 104T
5     IF (BETA.EQ.0.) GO TO 6                                       LOWE2070    A 105
      IFIND=1                                                       LOWE2080    A 106
      BET=CA*BETA                                                   LOWE2090    A 107
      X2=RE+H2                                                      LOWE2100    A 108
      ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA                   LOWE2110    A 109
      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)                               LOWE2120    A 110
      BET=BETA                                                      LOWE2130    A 111
      GO TO 8                                                       LOWE2140    A 112
6     RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2                           LOWE2150    A 113
      IF (RANGE.GT.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))   LOWE2160    A 114
7     IF (ANGLE.NE.0..AND.ANGLE.NE.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)LOWE2170    A 115
      IF (ANGLE.LT.0.) ANGLE=ANGLE+PI                               LOWE2180    A 116
      IF (RANGE.LT.0.0) RANGE=-RANGE                                LOWE2190    A 117
      BET=BET/CA                                                    LOWE2200    A 118
      PRINT 428, H1,H2,ANGLE,RANGE,BET,VIS                          LOWE2210    A 119
8     CONTINUE                                                      LOWE2220    A 120A
      DO 1002 I=1,34                                                LOWE2230      NEW
      DO 1002 J=1,KMAX                                              LOWE2240      NEW
 1002 WLAY(I,J)=0.                                                  LOWE2250      NEW
      SUMA=0.                                                       LOWE2260    A 120B
      IF(IXY.LE.2) READ 406,V1,V2,DV                                LOWE2270    A 121*
      IF(IXY.LE.2)PRINT 406,V1,V2,DV                                LOWE2280    A 122*
      IF (ITYPE.EQ.1) PRINT 407, H1,RANGE                           LOWE2290    A 123
      IF (ITYPE.EQ.2) PRINT 408, H1,H2,ANGLE                        LOWE2300    A 124
      IF (ITYPE.EQ.3) PRINT 409, H1,ANGLE                           LOWE2310    A 125
      IF (MODEL.EQ.0) M=7                                           LOWE2320    A 126A
      IF (VIS.GT.0.0) PRINT 417,VIS                                 LOWE2330    A 126B
      IF(VIS.LT.2.0.AND.VIS.GT.0.0) PRINT 442                       LOWE2340    A 126C
      IF (M.EQ.1) PRINT 410, M                                      LOWE2350    A 127
      IF (M.EQ.2) PRINT 411, M                                      LOWE2360    A 128
      IF (M.EQ.3) PRINT 412, M                                      LOWE2370    A 129
      IF (M.EQ.4) PRINT 413, M                                      LOWE2380    A 130
      IF (M.EQ.5) PRINT 415, M                                      LOWE2390    A 131
      IF (M.EQ.6) PRINT 414, M                                      LOWE2400    A 132
      IF (IHAZE.EQ.0.) PRINT 425                                    LOWE2410    A 133
      IF (VIS.LE.0.0.AND.IHAZE.GT.0) PRINT 416,IHAZE,HZ(IHAZE)      LOWE2420    A 134*
      AVW=10000./V1                                                 LOWE2430    A 135
      ALAM=10000./V2                                                LOWE2440    A 136
      RADMIN=1.0E+300 $RADMAX=0.  $  VKMIN=0.  $  VKMAX=0.          LOWE2450      NEW
      PRINT 418, V1,V2,DV,ALAM,AVW                                  LOWE2460    A 137
      AVW=0.5E-4*(V1+V2)                                            LOWE2470    A 138
      AVW=AVW*AVW                                                   LOWE2480    A 139
      CO=77.46+.459*AVW                                             LOWE2490    A 140
      CW=43.487-0.3473*AVW                                          LOWE2500    A 141
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (IFIND.EQ.1) GO TO 15                                        LOWE2610    A 142
9     IF (IFIND.EQ.1) CALL ANGL (H1,H2,ANGLE,BETA,LEN,ML)             LOWE2620    A 143*
      IFIND=0                                                         LOWE2630    A 144
      IF (JP.EQ.0) PRINT 427                                          LOWE2640    A 146*
      IF (ITYPE.EQ.1) GO TO 15                                        LOWE2650    A 147
      DO 11 K=1,KMAX                                                  LOWE2660      NEW
      VH(K)=0.0                                                       LOWE2670    A 149
11    CONTINUE                                                        LOWE2680    A 150
      BETA=0.0                                                        LOWE2690    A 151-
      SR=0.0                                                          LOWE2700    A 153
      IP=0                                                            LOWE2710    A 154-
C**** NOW DEFINE CONSTANT PRESSURE PATH QUANTITES  EH(1-6)             LOWE2620    A 156
      Y=CA*ANGLE                                                      LOWE2630    A 157
      SPHI=SIN(Y)                                                     LOWE2640    A 158
      R1=(RE+H1)*SPHI                                                 LOWE2650    A 159
      IF (H1.GT.Z(NL)) GO TO 13                                       LOWE2660    A 160
      GO TO 15                                                        LOWE2670    A 161
13    X=(RE+Z(NL))/(RE+H1)                                            LOWE2680    A 162
      IF (SPHI.GT.X) GO TO 14                                         LOWE2690    A 163
      H1=Z(NL)                                                        LOWE2700    A 164
      J1=NL                                                           LOWE2710    A 165
      SPHI=SPHI/X                                                     LOWE2720    A 166
      ANGLE=180.0-ASIN(SPHI)/CA                                       LOWE2730    A 167
      R1=(RE+H1)*SPHI                                                 LOWE2740    A 168
      GO TO 15                                                        LOWE2750    A 170
14    HMIN=R1-RE                                                      LOWE2760    A 171
      PRINT 433, HMIN                                                 LOWE2770    A 172
      GO TO 95                                                        LOWE2780    A 173
15    DO 17 I=1,NL                                                    LOWE2790    A 174
      PS=P(M,I)/1013.0                                                LOWE2800    A 175
      TS=273.15/T(M,I)                                                LOWE2810    A 176A
      IF(M1.GT.0.AND.M.LT.7)TS=273.15/T(M1,I)                         LOWE2820    A 176B
      X=PS*TS                                                         LOWE2830    A 177
      PT=PS*SQRT(TS)                                                  LOWE2840    A 178
      D=0.1*WH(M,I)                                                   LOWE2850    A 179
      IF(M2.GT.0.AND.M.LT.7) D=0.1*WH(M2,I)                           LOWE2860    A 180*
      EH(1,I)=D*PT**0.9                                               LOWE2870    A 181*
      EH(2,I)=X*PT**0.75                                              LOWE2880    A 182*
      EH(4,I)=0.8*PT*X                                                LOWE2890    A 183
      PPW=4.56E-5*D*273.15/TS                                         LOWE2900    A 184*
      TS1=(296.0/273.15)*TS                                           LOWE2910   *A 185A
      EH(5,I)=D*PPW*EXP(6.08*(TS1-1.0))+0.002*D*(PS-PPW)              LOWE2920   *A 185B
      EH(10,I)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(TS1-1.0))              LOWE2930   *A 185C
      EH(6,I)=X                                                       LOWE2940    A 186
      HAZE=HZ1(I)                                                     LOWE2950    A 187
      IF(M.EQ.7) HAZE=AHAZE(I)                                        LOWE2960    A 188*
      IF(Z(I).GE.5.0) GO TO 155                                       LOWE2970    A 189*
      IF(M.NE.7.AND.IHAZE.EQ.2) HAZE=HZ2(I)                           LOWE2980    A 190A
      IF(IHAZE.EQ.2.AND.M.EQ.7)HAZE=AHZ2(I)                           LOWE2990    A 190B
      IF(VIS.LE.0.0) GO TO 150                                        LOWE3000    A 190C
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF(M.NE.7) HAZE=6.389*(HZ2(I)-HZ1(I))/VIS+HZ1(I)/5.-HZ2(I)/23.)   LOWE3010   A 190D
      IF (M.NE.7) GO TO 150                                             LOWE3020   A 190E
      HAZE=6.389*((AHZ2(I)-AHAZE(I))/VIS+AHAZE(I)/5.0-AHZ2(I)/23.0)     LOWE3030   A 190F
150   IF(HAZE.LT.0.0) HAZE=0.0                                          LOWE3040   A 190G
      EH(7,I)=HAZE/HZ1(1)                                               LOWE3050   A 191A
      IF(MODEL.EQ.7) EH(7,I)=HAZE/AHAZE(1)                              LOWE3060   A 191B
      EH(8,I)=46.6667*WO(M,I)                                           LOWE3070   A 192
      IF(M3.GT.0.AND.M.LT.7) EH(8,I)=46.667*WO(M3,I)                    LOWE3080   A 193A
      EH(3,I)=EH(8,I)*PT**0.4                                           LOWE3090   A 193B
C EH(11,I)=HNO3 ABSORBER AMOUNT (ATM-CM)/KM                              LOWE3100     NEW
      EH(11,I)=PS*TS*HMIX(I)*1.0E-04                                    LOWE3110     NEW
      IF(MODEL.EQ.0.OR.MODEL.EQ.7) EH(11,I)=PS*TS*HSTOR(I)*1.0 E-04     LOWE3120     NEW
      EH(9,I)=1.0                                                       LOWE3130   A 1932
      REF=1.0E-6*(C0*X*1013.0/273.16-PPW*CW)                            LOWE3140  *A 1950
      IF (I.EQ.NL) GO TO 16                                             LOWE3150   A 194
      IF (MODEL.EQ.0.AND.I.GE.1) GO TO 26                               LOWE3160   A 195A
      T2=T(M,I+1)                                                       LOWE3170   A 195B
      W2=WH(M,I+1)                                                      LOWE3180   A 195C
      IF(M1.GT.0)T2=T(M1,I+1)                                           LOWE3190   A 195D
      IF(M2.GT.0)W2=WH(M2,I+1)                                          LOWE3200   A 195E
      PPW=4.56E-6*W2*T2                                                 LOWE3210   A 196*
      EH(10,I)=0.5*(REF+1.0E-6*(C0*P(M,I+1)/T2-PPW*CW))                 LOWE3220  *A 197*
16    IF (I.EQ.NL) EH(9,I)=0.                                           LOWE3230   A 198*
      IF (H1.GE.Z(I)) J1=I                                              LOWE3240   A 199*
      IF(LDIND.EQ.0.OR.JP.EQ.0) PRINT 434, I,Z(I),(EH(K,I),K=1,KMAX)    LOWE3250     NEW
      EH(9,I)=EH(9,I)+1.0                                               LOWE3260   A 201
17    CONTINUE                                                          LOWE3270   A 202
170   IF (IFIND.EQ.1) GO TO 9                                           LOWE3280   A 203
      IP=1                                                              LOWE3290   A 204
      IK=0                                                              LOWE3300   A 205
      X1=H1                                                             LOWE3310   A 206
      CALL POINT (H1,YN,N,NP1,TX,IP)                                    LOWE3320   A 207
      J1=N                                                              LOWE3330   A 208
      TX1-TX(9)                                                         LOWE3340   A 209
      DO 18 K=1,KMAX                                                    LOWE3350     NEW
18    F(K)=TX(K)                                                        LOWE3360   A 211
      IF (ITYPE.EQ.1) GO TO 26                                          LOWE3370   A 212
      IF (ITYPE.EQ.3) H2=Z(NL)                                          LOWE3380   A 213
      IF (ANGLE.GT.90.0) GO TO 28                                       LOWE3390   A 214
19    IF (ANGLE.GT.90.0.AND.NP1.GT.0) J1=J1+1                           LOWE3400   A 215
      J2=NL                                                             LOWE3410   A 216
      IF (ITYPE.EQ.3) GO TO 20                                          LOWE3420   A 217
      CALL POINT (H2,YN,N,NP,TX,IP)                                     LOWE3430   A 218
      J2=N                                                              LOWE3440   A 219
      IF (NP.GT.0) J2=J2-1                                              LOWE3450   A 220
20    DO 21 K=1,KMAX                                                    LOWE3460     NEW
       IF(K.EQ.9) GO TO 21                                              LOWE3470  *A 221B
      EH(K,J1)=F(K)                                                     LOWE3480   A 222
      IF (ITYPE.EQ.3) GO TO 21                                          LOWE3490   A 223
      EH(K,J2+1)=TX(K)                                                  LOWE3500   A 224
```

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
21    CONTINUE                                                  LOWE3510  A 225
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)                         LOWE3520  A 226
C**** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)               LOWE3530  A 227
      IF (JP.EQ.0) PRINT 420                                    LOWE3540  A 228*
      DO 1020 K=1,KMAX                                          LOWE3550    NEW
 1020 W(K)=0.                                                   LOWE3560    NEW
      DO 25 I=J1,J2                                             LOWE3570  A 229
      X1=Z(I)                                                   LOWE3580  A 230
      X2=Z(I+1)                                                 LOWE3590  A 231
      IF (I.EQ.J1) X1=H1                                        LOWE3600  A 232
      IF (I.EQ.J2) X2=H2                                        LOWE3610  A 233
      DZ=X2-X1                                                  LOWE3620  A 234
      IF (I.EQ.NL) DZ=Z(I)-Z(I-1)                               LOWE3630  A 235
      DS=DZ                                                     LOWE3640  A 236
C***** UPWARD TRAJECTORY                                        LOWE3650  A 237
      RX=(RE+X1)/(RE+X2)                                        LOWE3660  A 238
      THETA=ASIN(SPHI)/CA                                       LOWE3670  A 239
      PHI=ASIN(SPHI*RX)/CA                                      LOWE3680  A 240
      BET=THETA-PHI                                             LOWE3690  A 241
      SALP=RX*SPHI                                              LOWE3700  A 242
      IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI           LOWE3710  A 243
      BETA=BETA+BET                                             LOWE3720  A 244
      PSI=BETA+PHI-ANGLE                                        LOWE3730  A 245
      PHI=180.-PHI                                              LOWE3740  A 246
      SR=SR+DS                                                  LOWE3750  A 247
      JEXTRA=0                                                  LOWE3760    NEW
      DO 1024 K=1,KMAX                                          LOWE3770    NEW
      EV=DS*EH(K,I)                                             LOWE3780  A 249
      IF (I.EQ.NL) GO TO 22                                     LOWE3790  A 250
      IF (EH(K,I).EQ.0.0.OR.EH(K,I+1).EQ.0.0) GO TO 23          LOWE3800  A 251
      IF (EH(K,I).EQ.EH(K,I+1)) GO TO 24                        LOWE3810  A 252
      EV=DS*(EH(K,I)-EH(K,I+1))/ALOG(EH(K,I)/EH(K,I+1))         LOWE3820  A 253
      GO TO 24                                                  LOWE3830  A 254
22    IF (EH(K,I).EQ.0.0) GO TO 23                              LOWE3840  A 255
      IF (EH(K,I-1).EQ.0.0) GO TO 23                            LOWE3850  A 256
      IF (EH(K,I).EQ.EH(K,I-1)) GO TO 24                        LOWE3860  A 257
      EV=EV/ALOG(EH(K,I-1)/EH(K,I))                             LOWE3870  A 258
      GO TO 24                                                  LOWE3880  A 259
23    EV=0.                                                     LOWE3890  A 260
24    VH(K)=VH(K)+EV                                            LOWE3900  A 261
      IF(I.EQ.JSTOR) GO TO 1023                                 LOWE3910    NEW
 1022 WLAY(I,K)=EV+W(K)                                         LOWE3920    NEW
      W(K)=0.                                                   LOWE3930    NEW
      GO TO 1024                                                LOWE3940    NEW
 1023 W(K)=EV                                                   LOWE3950    NEW
      IF(J1.NE.J2) GO TO 1024                                   LOWE3960    NEW
      WLAY(J2+1,K)=W(K)                                         LOWE3970    NEW
      W(K)=0.                                                   LOWE3980    NEW
      JEXTRA=1                                                  LOWE3990    NEW
 1024 CONTINUE                                                  LOWE4000    NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (JP.EQ.0) PRINT 435, I,X1,(VH(L),L=1,8),PSI,PHI,BETA,THETA,SR  LOWE4010   A 262*
      IF (I.GE.NL) GO TO 25                                             LOWE4020   A 263
      IF (I+1.EQ.J2) EH(9,I+1)=YN                                       LOWE4030   A 264
      IF (I.EQ.J1) EH(9,I)=TX1                                          LOWE4040   A 265
      RN=EH(9,I+1)/EH(9,I)                                              LOWE4050   A 266
      SPHI=SPHI*RX/RN                                                   LOWE4060   A 267
      IF (SALP.GE.RN) SPHI=SALP                                         LOWE4070   A 268
25    CONTINUE                                                          LOWE4080   A 269
      GO TO 47                                                          LOWE4090   A 270
C**** HORIZONTAL PATH                                                    LOWE4100   A 271
26    DO 27 K=1,KMAX                                                    LOWE4110     NEW
      W(K)=RANGE*EH(K,1)                                                LOWE4120   A 273*
      IF (MODEL.GT.0) W(K)=RANGE*TX(K)                                  LOWE4130   A 274*
      VH(K)=W(K)                                                        LOWE4140     NEW
27    CONTINUE                                                          LOWE4150   A 275
      GO TO 49                                                          LOWE4160   A 276
28    CONTINUE                                                          LOWE4170   A 277
C****   DOWNWARD TRAJECTORY                                             LOWE4180   A 278
      K2=0                                                              LOWE4190   A 279
      IF (NP1.EQ.1) J1=J1-1                                             LOWE4200   A 280
      J2=J1+1                                                           LOWE4210   A 281
      J=J1+1                                                            LOWE4220   A 283
      YN1=YN                                                            LOWE4230   A 282
      IF (H2.GT.Z(J1+1).OR.H1.EQ.H2) GO TO 30                           LOWE4240   A 284
      IF (NP1.EQ.1.AND.H2.GE.Z(J1+1)) GO TO 30                          LOWE4250   A 285
      CALL POINT (H2,YN,N,NP2,TX,IP)                                    LOWE4260   A 286
      DO 29 K=1,KMAX                                                    LOWE4270     NEW
29    W(K)=TX(K)                                                        LOWE4280   A 288
      TX2=TX(9)                                                         LOWE4290   A 289
      YN2=YN                                                            LOWE4300   A 290
      IF (H2.LT.H1) H=H2                                                LOWE4310   A 291
      J2=N                                                              LOWE4320   A 292
      IF (J1.EQ.J2) TX2=TX1+YN2-EH(9,N)                                 LOWE4330   A 293
      IF (H2.GT.H1) TX1=TX2                                             LOWE4340   A 294
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2                                LOWE4350   A 295
30    A0=(RE+H1)*SPHI*YN1                                               LOWE4360   A 296
      IF (H2.GE.H1) YN2=YN1                                             LOWE4370   A 297
      DO 31 I=1,J1                                                      LOWE4380   A 298
      HMIN=A0/EH(9,I)-RE                                                LOWE4390   A 299
      IF (I.EQ.J1) HMIN=A0/YN1-RE                                       LOWE4400   A 300
      JMIN=I                                                            LOWE4410   A 301
      IF (HMIN.LE.Z(I+1)) GO TO 32                                      LOWE4420   A 302
31    CONTINUE                                                          LOWE4430   A 303
32    X=HMIN                                                            LOWE4440   A 304
      IF (HMIN.LE.0) GO TO 34                                           LOWE4450   A 305
      CALL POINT (X,YN,N,NP,TX,IP)                                      LOWE4460   A 306
      JMIN=N                                                            LOWE4470   A 307
      TX3=TX(9)                                                         LOWE4480   A 308
      IF (J2.EQ.N.OR.J1.EQ.N) TX3=YN2+TX(9)-EH(9,N)                     LOWE4490   A 309
      IF(TX3.LT.0.0)TX3=TX(9)                                           LOWE4500   A 309*
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      IF (J1.EQ.N.AND.H2.GE.H1) GO TO 33                          LOWE4510   A 310
      HMIN=A0/TX3-RE                                              LOWE4520   A 311
      IF (ABS(X-HMIN).GT.0.0001) GO TO 32                         LOWE4530   A 312
 33   IF (J1.EQ.N.AND.H2.GE.H1) YN1=TX3                           LOWE4540   A 313
      IF (J2.EQ.N.AND.J1.NE.J2) YN2=TX3                           LOWE4550   A 314
      IF (H2.GE.H1) TX2=TX3                                       LOWE4560   A 315
      IF (H2.GE.H1) J2=N                                          LOWE4570   A 316
      IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN                          LOWE4580   A 317
      PRINT 436, HMIN                                             LOWE4590   A 318
      IF(H2.LT.HMIN) J2=N                                         LOWE4600   A 318+
      IF (H2.LT.HMIN) PRINT 440, HMIN                             LOWE4610   A 319
      GO TO 35                                                    LOWE4620   A 320
 34   PRINT 436, HMIN                                             LOWE4630   A 321
      IF (H2.LT.H1) GO TO 35                                      LOWE4640   A 322
      IF (ITYPE.EQ.3.OR.H2.GE.H1) PRINT 437                       LOWE4650   A 323
      ITYPE=2                                                     LOWE4660   A 324
      TX2=EH(9,1)                                                 LOWE4670   A 325
      JMIN=0                                                      LOWE4680   A 326
      J2=1                                                        LOWE4690   A 327
      H2=0.0                                                      LOWE4700   A 328
      H=0.0                                                       LOWE4710   A 329
C****  NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)                 LOWE4720   A 330
 35   IF (JF.EQ.0) PRINT 420                                      LOWE4730   A 331*
      JSTOR=J-1                                                   LOWE4740     NEW
      DO 40 I=1,NL                                                LOWE4750   A 332
      J=J-1                                                       LOWE4760   A 333
      REF=EH(9,J)                                                 LOWE4770   A 334
      IF (I.EQ.1) REF=YN1                                         LOWE4780   A 335
      IF (I.EQ.1.AND.K2.EQ.1) REF=YN2                             LOWE4790   A 336
      IF (J.EQ.J2.AND.K2.EQ.0) REF=TX2                            LOWE4800   A 337
      IF (I.NE.1) X1=Z(J+1)                                       LOWE4810   A 338
      X2=Z(J)                                                     LOWE4820   A 339
      IF (J.EQ.J2.AND.K2.EQ.0) X2=H                               LOWE4830   A 340
      IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN                          LOWE4840   A 341
      HM=(RE+X1)*SPHI-RE                                          LOWE4850   A 342
      IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM                          LOWE4860   A 343
      RX=(RE+X1)/(RE+X2)                                          LOWE4870   A 344
      DS=X1-X2                                                    LOWE4880   A 345
      ALP=90.0                                                    LOWE4890   A 346
      THET=ASIN(SPHI)/CA                                          LOWE4900   A 347
      SALP=RX*SPHI                                                LOWE4910   A 348
      IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA                 LOWE4920   A 349
      BET=ALP-THET                                                LOWE4930   A 350
      IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI            LOWE4940   A 351
      THETA=180.0-THET                                            LOWE4950   A 352
      BETA=BETA+BET                                               LOWE4960   A 353
      PSI=BETA-ALP-ANGLE+180.0                                    LOWE4970   A 354
      SR=SR+DS                                                    LOWE4980   A 355
      DO 1039 K=1,KMAX                                            LOWE4990     NEW
      AJ=EH(K,J)                                                  LOWE5000   A 357
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      BJ=EH(K,J+1)                                                     LOWE5010   A 358
      IF (J.EQ.J1) BJ=E(K)                                             LOWE5020   A 359
      IF (J.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) AJ=H(K)                  LOWE5030   A 360
      IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)                             LOWE5040   A 361
      IF (J.EQ.JMIN.AND.ABS(H2-HM).LT.1.0E-5) AJ=TX(K)                 LOWE5050   A 362
      IF (K2.EQ.0) GO TO 36                                            LOWE5060   A 363
      IF (J.EQ.J2) BJ=H(K)                                             LOWE5070   A 364
      IF (J.EQ.JMIN) AJ=TX(K)                                          LOWE5080   A 365
36    IF (AJ.EQ.0.0.OR.BJ.EQ.0.0) GO TO 38                             LOWE5090   A 366
      IF (AJ.EQ.BJ) GO TO 37                                           LOWE5100   A 367
      EV=DS*(AJ-BJ)/ALOG(AJ/BJ)                                        LOWE5110   A 368
      GO TO 39                                                         LOWE5120   A 369
37    EV=DS*AJ                                                         LOWE5130   A 370
      GO TO 39                                                         LOWE5140   A 371
38    EV=0.0                                                           LOWE5150   A 372
39    VH(K)=VH(K)+EV                                                   LOWE5160   A 373
 1039 HLAY(J,K)=EV                                                     LOWE5170     NEW
      IF (JP.EQ.0) PRINT 435, J,X1,(VH(L),L=1,8),PSI,ALP,BETA,THETA,SR LOWE5180   A 374*
      IF (J.EQ.J2.AND.H2.GE.H1) GO TO 45                               LOWE5190   A 375
      IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 43                              LOWE5200   A 376
      IF (J.NE.1) RN=REF/EH(9,J-1)                                     LOWE5210   A 377
      IF (J.EQ.J2+1) RN=REF/TX2                                        LOWE5220   A 378
      IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2                              LOWE5230   A 379
      IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TX3                        LOWE5240   A 380
      IF (SALP.GE.RN) RN=1.0                                           LOWE5250   A 381
      SPHI=SALP*RN                                                     LOWE5260   A 382
      IF (J.EQ.J2.AND.K2.EQ.0) GO TO 41                                LOWE5270   A 383
40    CONTINUE                                                         LOWE5280   A 384
41    IF (HMIN.LE.0) GO TO 47                                          LOWE5290   A 385
      IF (LEN.EQ.0) PRINT 438                                          LOWE5300   A 386
      IF (LEN.EQ.0) GO TO 47                                           LOWE5310   A 387
      IF (LEN.EQ.1) PRINT 439                                          LOWE5320   A 388
      K2=1                                                             LOWE5330   A 389
      X1=X2                                                            LOWE5340   A 390
      IF (ABS(X1-HMIN).LE.0.001) GO TO 47                              LOWE5350   A 391
      H=HMIN                                                           LOWE5360   A 392
      J=J2+1                                                           LOWE5370   A 393
      IF (NP2.EQ.1) J=J-1                                              LOWE5380   A 394
      B=BETA                                                           LOWE5390   A 395
      PH=180.0-ASIN(SPHI)/CA                                           LOWE5400   A 396
      TS=SR                                                            LOWE5410   A 397
      PS=PSI                                                           LOWE5420   A 398
      DO 42 K=1,KMAX                                                   LOWE5430     NEW
42    E(K)=VH(K)                                                       LOWE5440   A 400
      GO TO 35                                                         LOWE5450   A 401
43    BETA=2.*BETA-B                                                   LOWE5460   A 402
      PSI=2.*PSI-PS                                                    LOWE5470   A 403
      SR=2.*SR-TS                                                      LOWE5480   A 404
C      LONG PATH  TAKEN                                                LOWE5490   A 405
      PHI=PH                                                           LOWE5500   A 406
```

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      DO 44 K=1,KMAX                                                    LOWE5510       NEW
44    VH(K)=2.*VH(K)-E(K)                                               LOWE5520     A 408
      GO TO 47                                                          LOWE5530     A 409
45    DO 46 K=1,KMAX                                                    LOWE5540       NEW
46    VH(K)=2.0*VH(K)                                                   LOWE5550     A 411
      BETA=2.0*BETA                                                     LOWE5560     A 412
      SR=2.0*SR                                                         LOWE5570     A 413
      IF (H2.EQ.H1) GO TO 47                                            LOWE5580     A 414
      RN=TX1/YN1                                                        LOWE5590     A 415
      SPHI=SIN(ANGLE*CA)                                                LOWE5600     A 416
      IF (SPHI.LT.RN) SPHI=SPHI/RN                                      LOWE5610     A 417
      GO TO 19                                                          LOWE5620     A 418
47    CONTINUE                                                          LOWE5630     A 419
       IF(ANGLE.GT.90.0) PRINT 406,HN                                   LOWE5640     A 419F
      DO 48 K=1,KMAX                                                    LOWE5650       NEW
      W(K)=VH(K)                                                        LOWE5660     A 421
48    CONTINUE                                                          LOWE5670     A 422
49    WRITE (6,419)                                                     LOWE5680     A 423
      WRITE (6,1155)                                                    LOWE5690       NEW
      WRITE(6,421) (W(I),I=1,8),W(13),W(11)                             LOWE5700       NEW
      WRITE(7,3000) M,IHAZE,ITYPE,H1,ANGLE,HMIN,V1,V2,DV                LOWE5710       NEW
 3000 FORMAT(3I3,6F11.4)                                                LOWE5720       NEW
      I=1                                                               LOWE5730     A 425
      L=1                                                               LOWE5740     A 426
      IV1=V1/5.0                                                        LOWE5750     A 427
      IV2=V2/5.+.99                                                     LOWE5760     A 428
      IV1=5*IV1                                                         LOWE5770     A 429
      IV2=5*IV2                                                         LOWE5780     A 430
      IF (IV1.LT.350) IV1=350                                           LOWE5790     A 431
      IF (IV2.GT.50000) IV2=50030                                       LOWE5800     A 432
      IF (DV.LT.5.) DV=5.                                               LOWE5810     A 433
      TCV=OV                                                            LOWE5820     A 434
      IV=IV1-IDV                                                        LOWE5830     A 435
      ICOUNT=0                                                          LOWE5840     A 436
      IF(IEMISS.EQ.0) GO TO 50                                          LOWE5850       NEW
      RADSUM=0.0                                                        LOWE5860       NEW
      FACTOR=0.5                                                        LOWE5870       NEW
      CALL PATH(WLAY,WPATH,IBBY)                                        LOWE5880       NEW
      PRINT 1156                                                        LOWE5890       NEW
      PRINT 1157                                                        LOWE5900       NEW
      IF(IEMISS.EQ.0) IKMAX=IKLO                                        LOWE5910       NEW
C****  DEGINING OF TRANSMITTANCE CALCULATIONS                           LOWE5920     A 437
50    IV=IV+IDV                                                         LOWE5930     A 438A
      SUMV=0.                                                           LOWE5940       NEW
      TLOLD=1.       $  TSOLD=1.                                        LOWE5950       NEW
       IKLO=1                                                           LOWE5960       NEW
      IF(IEMISS.EQ.0) IKLO=IKMAX                                        LOWE5970       NEW
       DO 1050 IK=IKLO,IKMAX                                            LOWE5980       NEW
      IF(IEMISS.EQ.0) GO TO 1055                                        LOWE5990       NEW
       DO 1052 K=1,KMAX                                                 LOWE6000       NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      W(K)=WPATH(IK,K)                                          LOWE6010     NEW
 1052 CONTINUE                                                  LOWE6020     NEW
1055  IJ=IK                                                     LOWE6030     NEW
      IF(JP.NE.0) GO TO 52                                      LOWE6040   A 438B
      IF (ICOUNT.EQ.0) GO TO 51                                 LOWE6050   A 439
      IF (ICOUNT.EQ.50) GO TO 51                                LOWE6060   A 440
      GO TO 52                                                  LOWE6070   A 441
51    ICOUNT=0                                                  LOWE6080   A 442
      IF(IEMISS.EQ.0) PRINT 422                                 LOWE6090     NEW
52    DO 53 K=1,KMAX                                            LOWE6100     NEW
      TX(K)=0.0                                                 LOWE6110   A 445
      IF (K.LT.4) TX(K)=1.0                                     LOWE6120   A 446
53    CONTINUE                                                  LOWE6130   A 447
      ICOUNT=ICOUNT+1                                           LOWE6140   A 448
      SUM=0.0                                                   LOWE6150   A 449
      V=IV                                                      LOWE6160   A 450
      I=(IV-350)/5+1                                            LOWE6170   A 451
C  **********************  HNO3                                 LOWE6180     NEW
C     HNO3 ABSORPTION CALCULATION                               LOWE6190     NEW
      CALL HNO3 (V,HABS)                                        LOWE6200     NEW
      TX(11)=HABS*W(11)                                         LOWE6210     NEW
      SUM=SUM+TX(11)                                            LOWE6220     NEW
      IF(IV.LT.679) GO TO 72                                    LOWE6230  *A 452*
      IF(IV.LE.3000) GO TO 61                                   LOWE6240  *A 453*
C*********   MOLECULAR SCATTERING                               LOWE6250   A 454
      C6=9.807E-21*(V**4.0117)                                  LOWE6260   A 455
      TX(6)=C6*W(6)                                             LOWE6270   A 456
      SUM=SUM+TX(6)                                             LOWE6280   A 457
      IF (IV.LT.9200) GO TO 72                                  LOWE6290   A 458
      IF (IV.LT.13000) GO TO 69                                 LOWE6300   A 459
C*********   UV OZONE                                           LOWE6310   A 460
      IF (IV.LE.23400) GO TO 54                                 LOWE6320   A 461
      IF (IV.GE.27500) GO TO 55                                 LOWE6330   A 462
      GO TO 87                                                  LOWE6340   A 463
54    XX=200.0                                                  LOWE6350   A 464
      XI=(V-13000.0)/XX+1.0                                     LOWE6360   A 465
      L1=1                                                      LOWE6370   A 466
      L2=53                                                     LOWE6380   A 467
      GO TO 56                                                  LOWE6390   A 468
55    XX=500.0                                                  LOWE6400   A 469
      XI=(V-27500.0)/XX+57.0                                    LOWE6410   A 470
      L1=57                                                     LOWE6420   A 471
      L2=102                                                    LOWE6430   A 472
56    DO 57 N=L1,L2                                             LOWE6440   A 473
      XD=XI-FLOAT(N)                                            LOWE6450   A 474
      IF (XD) 59,58,57                                          LOWE6460   A 475
57    CONTINUE                                                  LOWE6470   A 476
58    TX(8)=W(8)*C8(N)                                          LOWE6480   A 477
      GO TO 60                                                  LOWE6490   A 478
59    TX(8)=C8(N)+XD*(C8(N)-C8(N-1))                            LOWE6500   A 479
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      TX(8)=W(8)*TX(8)                                          LOWE6510   A 480
60    SUM=SUM+TX(8)                                             LOWE6520   A 481
      IF(IV.GT.14500)GO TO 87                                   LOWE6530   A 482*
      GO TO 59                                                  LOWE6540   A 483
C********  WATER VAPOR CONTINUUM 10 MICRON REGION                LOWE6550  *A 484
61    IF(IV.GT.1350) GO TO 62                                   LOWE6560  *A 485
      TX(5)=(4.18+5578.0*EXP(-7.87E-3*V))*W(5)                  LOWE6570  *A 486
      GO TO 66                                                  LOWE6580  *A 487
62    IF(IV.LT.2350) GO TO 68                                   LOWE6590  *A 488
C********  WATER VAPOR CONTINUUM 4 MICRON REGION                 LOWE6600  *A 489
      XI=(V-2350.0)/50.0+1.0                                    LOWE6610  *A 490
      NH=XI+1.001                                               LOWE6620  *A 491
      XH=XI-FLOAT(NH)                                           LOWE6630  *A 492
      TX(5)=C5(NH)                                              LOWE6640  *A 493
64    TX(5)=TX(5)+XH*(C5(NH)-C5(NH-1))                          LOWE6650  *A 496
65    TX(5)=TX(5)*W(10)                                         LOWE6660  *A 497
66    SUM=SUM+TX(5)                                             LOWE6670  *A 498
      IF(IV.LE.1350.OR.IV.GT.2740) GO TO 72                     LOWE6680  *A 499
C********  NITROGEN CONTINUUM                                    LOWE6690   A 500
68    IF (IV.LT.2080) GO TO 72                                  LOWE6700   A 501
      K4=I-346                                                  LOWE6710   A 502
      TX(4)=C4(K4)*W(4)                                         LOWE6720   A 503
      SUM=SUM+TX(4)                                             LOWE6730   A 504
      GO TO 72                                                  LOWE6740   A 505
C********  WATER VAPOUR                                          LOWE6750   A 506
69    IF (IV.LT.12800.AND.IV.GE.9875) GO TO 70                  LOWE6760   A 507
      IF (IV.LE.14520.AND.IV.GE.13400) GO TO 71                 LOWE6770   A 508
      GO TO 76                                                  LOWE6780   A 509
70    I=I-135                                                   LOWE6790   A 510
      GO TO 72                                                  LOWE6800   A 511
71    I=I-255                                                   LOWE6810   A 512
72    K1=1                                                      LOWE6820   A 513
      IF (W(1).LT.1.0E-20) GO TO 76                             LOWE6830   A 514
      WS1=ALOG10(W(1))+C1(I)                                    LOWE6840   A 515
      IF (WS1.LT.-2.3468) TX(1)=1.-.087787*EXP(1.855595*WS1)    LOWE6850      NEW
      IF (WS1.LT.-2.3468) GO TO 76                              LOWE6860   A 516
      IF (WS1.GT.3.5682) GO TO 75                               LOWE6870   A 517
      IF (WS1.GT.2.0) K1=40                                     LOWE6880   A 518
      DO 73 K=K1,67                                             LOWE6890   A 519
      IF (WS1.LE.FW(K)) GO TO 74                                LOWE6900   A 520
73    CONTINUE                                                  LOWE6910   A 521
74    TX(1)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS1)/(FW(K)-FW(K-1))   LOWE6920   A 522
      GO TO 76                                                  LOWE6930   A 523
75    TX(1)=0.0                                                 LOWE6940   A 524
76    CONTINUE                                                  LOWE6950   A 525
C********  UNIFORMLY MIXED GASES                                 LOWE6960   A 526
      IF (IV.LT.8060.AND.IV.GE.500) GO TO 77                    LOWE6970   A 527
      IF (IV.LT.13190.AND.IV.GT.12970) GO TO 78                 LOWE6980   A 528
      GO TO 83                                                  LOWE6990   A 529
77    J=I-30                                                    LOWE7000   A 530
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      GO TO 79                                                  LOWE7010   A 531
78    J=(IV-12950)/5+1516                                       LOWE7020   A 532
79    IF(W(2).LT.1.0E-20) GO TO 83                              LOWE7030   A 533*
      K1=1                                                      LOWE7040   A 534
      WS2=ALOG10(W(2))+C2(J)                                    LOWE7050   A 535
      IF (WS2.LT.-2.3468) TX(2)=1.-.087787*EXP(1.855595*WS2)    LOWE7060     NEW
      IF (WS2.LT.-2.3468) GO TO 83                              LOWE7070   A 536
      IF (WS2.GT.3.5682) GO TO 82                               LOWE7080   A 537
      IF (WS2.GT.2.0) K1=40                                     LOWE7090   A 538
      DO 80 K=K1,67                                             LOWE7100   A 539
      IF (WS2.LE.FW(K)) GO TO 81                                LOWE7110   A 540
80    CONTINUE                                                  LOWE7120   A 541
81    TX(2)=TR(K)+(TR(K-1)-TR(K))*(FW(K)-WS2)/(FW(K)-FW(K-1))   LOWE7130   A 542
      GO TO 83                                                  LOWE7140   A 543
82    TX(2)=0.0                                                 LOWE7150   A 544
83    CONTINUE                                                  LOWE7160   A 545
C*********  OZONE                                               LOWE7170   A 546
      IF (IV.LT.575.OR.IV.GT.3270) GO TO 87                     LOWE7180   A 546+
      L=I-45                                                    LOWE7190   A 547
      K1=1                                                      LOWE7200   A 548
      IF (W(3).LT.1.0E-20) GO TO 87                             LOWE7210   A 549
      WS3=ALOG10(W(3))+C3(L)                                    LOWE7220   A 550
      IF (WS3.LT.-1.6778) TX(3)=1.-.055194*EXP(2.367853*WS3)    LOWE7230     NEW
      IF (WS3.LT.-1.6778) GO TO 87                              LOWE7240   A 551
      IF (WS3.GT.3.9345) GO TO 86                               LOWE7250   A 552
      IF (WS3.GT.1.5) K1=36                                     LOWE7260   A 553
      DO 84 K=K1,67                                             LOWE7270   A 554
      IF (WS3.LE.FO(K)) GO TO 85                                LOWE7280   A 555
84    CONTINUE                                                  LOWE7290   A 556-
85    TX(3)=TR(K)-(TR(K)-TR(K-1))*(FO(K)-WS3)/(FO(K)-FO(K-1))   LOWE7300   A 558
      GO TO 87                                                  LOWE7310   A 559
86    TX(3)=0.0                                                 LOWE7320   A 560
87    CONTINUE                                                  LOWE7330   A 561
C*********    AEROSOL EXTINCTION                                LOWE7340   A 562
      ALAM=1.0E+4/V                                             LOWE7350   A 563A
      XX=0.0                                                    LOWE7360   A 563B
      YY=0.0                                                    LOWE7370   A 563C
C*********  TEMPORARY FOG CORRECTION FOR VIS BELOW 2 KM.        LOWE7380   A 563D
C     IF(VIS.GT.0.0.AND.VIS.LT.2.0)   XX=0.158                  LOWE7390     NEW
C        TEMPORARY FOG SUPPRESSED                               LOWE7400     NEW
      IF (IHAZE.EQ.0.OR.XX.GT.0.0)    GO TO 90                  LOWE7410   A 564*
      DO 88 N=1,44                                              LOWE7420   A 565*
      XD=ALAM-VX(N)                                             LOWE7430   A 566*
      IF(XD)89,88,88                                            LOWE7440   A 567*
88    CONTINUE                                                  LOWE7450   A 568A
89    XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)               LOWE7460   A 568B
      YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)            LOWE7470   A 568C
90    TX(10)=YY*W(7)                                            LOWE7480   A 568D
      TX(7)=XX*W(7)                                             LOWE7490   A 569*
      SUM=SUM+TX(7)                                             LOWE7500   A 570
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      TX(9)=SUM                                                         LOWE7510   A 571
      DO 94 K=4,KMAX                                                    LOWE7520     NEW
      IF (TX(K).EQ.0.0) GO TO 92                                        LOWE7530   A 573
      IF (TX(K).LE.0.1) GO TO 91                                        LOWE7540   A 574
      IF (TX(K).GT.20.) GO TO 93                                        LOWE7550   A 575
      TX(K)=EXP(-TX(K))                                                 LOWE7560   A 576
      GO TO 94                                                          LOWE7570   A 577
91    TX(K)=1.0-TX(K)+0.5*TX(K)*TX(K)                                   LOWE7580   A 578
      GO TO 94                                                          LOWE7590   A 579
92    TX(K)=1.0                                                         LOWE7600   A 580
      GO TO 94                                                          LOWE7610   A 581
93    TX(K)=0.                                                          LOWE7620   A 582
94    CONTINUE                                                          LOWE7630   A 583
      TX(9)=TX(1)*TX(2)*TX(3)*TX(9)                                     LOWE7640   A 584
      IF (IV.GE.13000) TX(3)=TX(8)                                      LOWE7650   A 585
      IF(IEMISS.EQ.0) GO TO 1210                                        LOWE7660     NEW
      ALAM=1.0E+04/V                                                    LOWE7670     NEW
       BBIK =FF(TBBY(IK),V)                                             LOWE7680     NEW
      TLNEW    =(TX(9)*TX(10))/(TX(7)*TX(6))                            LOWE7690     NEW
      TSNEW     =(TX(7)*TX(6))/TX(10)                                   LOWE7700     NEW
       DTAU=TLOLD-TLNEW                                                 LOWE7710     NEW
      IF (DTAU.LT.1.0E-5.AND.TLNEW    .LT.1.0E-5) GO TO 1104            LOWE7720     NEW
      SUMV=SUMV+0.5*BBIK*DTAU*(TSOLD+TSNEW)                             LOWE7730     NEW
       TLOLD=TLNEW      $  TSOLD=TSNEW                                  LOWE7740     NEW
1050  CONTINUE                                                          LOWE7750     NEW
1104  CONTINUE                                                          LOWE7760     NEW
      TAUG=0                                                            LOWE7770     NEW
       IF(HMIN.LE.0.0.AND.IL.EQ.1) TAUG=TX(9)                           LOWE7780     NEW
      T1=T(M,1)                                                         LOWE7790     NEW
      IF(TBOUND.GT.0.0) T1=TBOUND                                       LOWE7800     NEW
      BBG=FF(T1,V)*TAUG                                                 LOWE7810     NEW
      IF (HMIN.LE.0) SUMV=SUMV+BBG                                      LOWE7820     NEW
      SUMVV=SUMV                                                        LOWE7830     NEW
      IF (IV.GT.IV1) FACTOR=1.0                                         LOWE7840     NEW
      IF (IV.GE.IV2) FACTOR=0.5                                         LOWE7850     NEW
      SUMV=(1.0E+04/V**2)*SUMV                                          LOWE7860     NEW
      RADSUM=RADSUM+DV*FACTOR*SUMV                                      LOWE7870     NEW
      IF(JP.EQ.0) PRINT 1160, V,ALAM,SUMV,SUMVV,RADSUM,TX(9)            LOWE7880     NEW
      IF(SUMV.GE.RADMAX) VRMAX=V                                        LOWE7890     NEW
      IF(SUMV.GE.RADMAX)  RADMAX=SUMV                                   LOWE7900     NEW
      IF(SUMV.LE.RADMIN) VRMIN=V                                        LOWE7910     NEW
      IF(SUMV.LE.RADMIN) RADMIN=SUMV                                    LOWE7920     NEW
       WRITE(7,3010) V,SUMV,SUMVV,RADSUM,TX(9),TX(1)                    LOWE7930     NEW
 3010 FORMAT(F10.1,11F10.3)                                             LOWE7940     NEW
 1210 TX(10)=1.-TX(10)                                                  LOWE7950     NEW
      AB=1.-TX(9)                                                       LOWE7960   A 586B
      IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB                              LOWE7970   A 586C
      SUMA=SUMA+AB*DV                                                   LOWE7980   A 586D
      IF(IEMISS.EQ.1) GO TO 1220                                        LOWE7990     NEW
      IF(JP.EQ.0) WRITE(6,423) IV,ALAM,TX(9),(TX(K),K=1,7),TX(10),SUMA  LOWE8000   A 587*
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
 1220 CONTINUE                                                           LOWE8010      NEW
      IF (IV.GE.IV2) GO TO 95                                            LOWE8020    A 588
      GO TO 50                                                           LOWE8030    A 589
95    READ 400, IXY                                                      LOWE8040    A 590
      IF(IEMISS.EQ.1)PRINT 1175,VRMIN,RADMIN,VRMAX,RADMAX                LOWE8050      NEW
 1175  FORMAT(* RADMIN * ,F12.3,E12.5,/,* RADMAX *,F12.3,E12.5)          LOWE8060      NEW
       ENDFILE 7                                                         LOWE8070      NEW
      JSTOR=0  $   IFINO=0                                               LOWE8080      NEW
      AB=1.0-SUMA/FLOAT(IV2-IV1)                                         LOWE8090      NEW
      PRINT 424, IV1,IV2,SUMA,AB                                         LOWE8100    A 591B
      IF(IEMISS.EQ.1) PRINT 443,RADSUM                                   LOWE8110      NEW
 443  FORMAT(* INTEGRATED RADIANCE =*,F12.5,*WATT CM -2  SR*)            LOWE8120      NEW
      PRINT 400,IXY                                                      LOWE8130    A 591C
      IF(IXY.EQ.0) GO TO 100                                             LOWE8140    A 591D
      GO TO (96,2,97,98,100),IXY                                         LOWE8150    A 591E
96    READ 406, V1,V2,DV                                                 LOWE8160    A 592
      AVW=10000./V1                                                      LOWE8170    A 593
      ALAM=10000./V2                                                     LOWE8180    A 594
      PRINT 418, V1,V2,DV,ALAM,AVW                                       LOWE8190    A 595
      SUMA=0.0                                                           LOWE8200    A 596*
      GO TO 47                                                           LOWE8210      NEW
97    IF(MODEL.EQ.0) GO TO 200                                           LOWE8220    A 598A
      GO TO 300                                                          LOWE8230    A 598B
98    READ 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE8240      NEW
      IF(IEMISS.EQ.1) PRINT 1170                                         LOWE8250      NEW
      IF(IEMISS.EQ.0) PRINT 1171                                         LOWE8260      NEW
      LENSTOR=LEN                                                        LOWE8270      NEW
      PRINT 400,MODEL,IHAZE,ITYPE,LEN,JP,IM,M1,M2,M3,ML,IEMISS,RO,TBOUND LOWE8280      NEW
      GO TO 200                                                          LOWE8290    A 598F
100   STOP                                                               LOWE8300    A 599*
400   FORMAT(11I3,2F10.3)                                                LOWE8310      NEW
 1170 FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE EMISSION MODE*)          LOWE8320      NEW
 1171 FORMAT(*1 PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE*)      LOWE8330      NEW
401   FORMAT (8F10.3)                                                    LOWE8340    A 601
402   FORMAT (F6.1,2(F10.3,F6.1,2E10.3))                                 LOWE8350    A 602
403   FORMAT (4(F6.3,2F7.4))                                             LOWE8360    A 603
404   FORMAT (15F5.2)                                                    LOWE8370    A 604
405   FORMAT (8E9.2)                                                     LOWE8380    A 605
406   FORMAT (7F10.3)                                                    LOWE8390    A 606
407   FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,LOWE8400    A 607
     1F7.3,3H KM)                                                        LOWE8410    A 608
408   FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 LOWE8420    A 609
     1=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)      LOWE8430    A 610
409   FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H LOWE8440    A 611
     1KM, ZENITH ANGLE =,F7.3,8H DEGREES)                                LOWE8450    A 612
410   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,11H = TROPICAL)              LOWE8460    A 613
411   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE SUMMER)    LOWE8470    A 614
412   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = MIDLATITUDE WINTER)    LOWE8480    A 615
413   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC SUMMER )    LOWE8490    A 616
414   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )    LOWE8500    A 617
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
415   FORMAT (/20X,18H MODEL ATMOSPHERE ,I1,21H = SUB-ARCTIC WINTER )    LOWE8510     A 618
416   FORMAT (/20X,18H        HAZE MODEL ,I1,3H = ,A5,13H VISUAL RANGE)  LOWE8520     A 619
417   FORMAT (/25X*HAZE MODEL  =*,F5.1,* KM VISUAL RANGE AT SEA LEVEL*) LOWE8530     A 620
418   FORMAT (/10X,21H FREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,1LOWE8540     A 621
     14H CM-1 FOR DV =,F6.1,9H CM-1   (,F6.2,* - *,F6.2,* MICRONS )*)   LOWE8550     A 622
419   FORMAT (/10X,38H EQUIVALENT SEA LEVEL ABSORBER AMOUNTS//21X110HWATLOWE8560     A 623
     1ER VAPOUR     CO2 ETC.         OZONE    NITROGEN (CONT)  H2O (CONT) LOWE8570     A 624
     2    MOL  SCAT      AEROSOL      OZONE(U-V)/24X,7HGM CM-2,13X,2HKM,1LOWE8580     A 625
     30X,6HATM CM,10X,2HKM,9X,7HGM CM-2,10X,2HKM,13X,2HKM,10X,6HATM CM) LOWE8590     A 626
420   FORMAT (1H1,///10X,*  VERTICAL PROFILES  *,64X,*PSI*,6X,*PHI*,6X,*LOWE8600     A 627
     1BETA*,4X,*THETA    RANGE*)                                        LOWE8610     A 628
421   FORMAT (/10X,8H W(1-8)=8(E14.3)/ 74X,E14.3,28X,E14.3/)            LOWE8620       NEW
422   FORMAT (1H1,/10X,32H FREQ WAVELENGTH  TOTAL      H2O,5X4HCO2+,5X,6LOWE8630     A 630*
     14HOZONE  N2 CONT  H2O CONT MOL SCAT  AEROSOL  AEROSOL   INTEGRATEDLOWE8640     A 631*
     2 /11X,14H CM-1  MICRONS,9(4X5HTRANS),4X,20H ABS      ABSORPTION )  LOWE8650     A 632*
  423 FORMAT(13X,I6,11F9.4        )                                     LOWE8660       NEW
424   FORMAT (* INTEGRATED ABSORPTION FROM*,I5,* TO*,I5,* CM-1 =*,F10.2,LOWE8670     A 634A
     1*,AVERAGE TRANSMITTANCE =*,F6.4)                                  LOWE8680     A 634B
425   FORMAT (10X,7F10.3)                                               LOWE8690     A 635
426   FORMAT (/20X,*AEROSOL SCATTERING NOT COMPUTED,IHAZE=0*)           LOWE8700     A 636
427   FORMAT (1H1,///10X,20H HORIZONTAL PROFILES/)                      LOWE8710     A 637
428   FORMAT (10X,* H1=*,F7.3,*KM,H2=*,F7.3,*KM,ANGLE=*,F8.4,*GEOM. RANGLOWE8720     A 638
     1E =*,F7.2,*KM,BETA=*,F8.5,*,VIS=*,F6.1)                           LOWE8730     A 639
429   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)                                LOWE8740     A 640*
430   FORMAT(10X,*INPUT METEOROLOGICAL DATA:*/10X,*Z=*,F7.2,* KM, P=*,F7LOWE8750     A 641*
     1.2,* MB,T=*,F5.1,* C, DEW PT.TEMP*,F5.1,* C, REL HUMIDITY=*,F5.1, LOWE8760     A 642*
     2* %, H2O DENSITY=*,1PE9.2,* GM M-3*/10X,* OZONE DENSITY=*,E9.2,* GLOWE8770     A 643*
     3M-3, VISUAL RANGE=*,0PF6.1,* KM,RANGE=*,F10.3,* KM *  )           LOWE8780     A 644*
431   FORMAT(6(F6.2,2F7.5))                                             LOWE8790     A 645*
432   FORMAT (* STARTING PARAMETERS H1 AND ANGLE HAVE BEEN REDEFINED:H1=LOWE8800     A 646
     1 *,F10.3,*ANGLE =*,F10.6)                                         LOWE8810     A 647
433   FORMAT (* TRAJECTORY MISSES EARTHS ATMOSPHERE. CLOSEST DISTANCE OFLOWE8820     A 648
     1 APPROACH IS*,F10.2,1X,/,1X,*END OF CALCULATION*)                 LOWE8830     A 649
434   FORMAT (10X,I4,F6.1,11(E10.3))                                    LOWE8840     A 650
435   FORMAT (I5,F7.1,8F10.3,4F9.4,F7.1)                                LOWE8850     A 651
436   FORMAT (* HMIN = *,F10.3)                                         LOWE8860     A 652
437   FORMAT (* PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H2 =LOWE8870     A 653
     1 0.0 KM*)                                                         LOWE8880     A 654
438   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKEN. LOWE8890     A 655
     1 FOR LONGER PATH SET LEN=1.*)                                     LOWE8900     A 656
439   FORMAT (* CHOICE OF TWO PATHS FOR THIS CASE -LONGEST PATH TAKEN.  LOWE8910     A 657
     1 FOR SHORT PATH SET LEN = 0 *)                                    LOWE8920     A 658
440   FORMAT (* H2 HAS SET LESS THAN HMIN AND HAS BEEN RESET EQUAL TO   LOWE8930     A 659
     1  HMIN I.E. H2 = *,F10.3)                                         LOWE8940     A 660
441   FORMAT(*  MODEL ATMOSPHERE NO. 7*,/ 4X,*Z (KM)*,3X,*P (MB)*,4X,   LOWE8950     A 661*
     1 *T (C) DEW PT %RH  H2O(GM,M-3) O3(GM,M-3) NO. DEN.*)             LOWE8960     A 662*
442   FORMAT(*  FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RALOWE8970     A 663*
     1NGE*,/,*  IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN LOWE8980     A 664*
     2BY THE TRANSMITTANCE AT 0.55 MICRONS*)                            LOWE8990     A 665*
1109  FORMAT (9I3)                                                      LOWE9000       NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
1155  FORMAT (118X,*NITRIC ACID*)                                          LOWE9010     NEW
1156  FORMAT (1H1,50X,*RADIANCE(WATTS/CM2-STER-XXX)*)                      LOWE9020     NEW
1157  FORMAT (30X,*FR(CM-1)  WVL(MICRON)      PER CM-1    PER MICRON*,*    LOWE9030     NEW
     1  INTEGRAL        TRANS*)                                            LOWE9040     NEW
 1160 FORMAT(30X,F8.1,F13.6,3E13.5,F13.6)                                  LOWE9050     NEW
      END                                                                  LOWE9060   A 666*
```

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE PATH(WLAY,WPATH,TBBY)
      COMMON Z(34),P(7,34),T(7,34),SH(11,34),WH(7,34),M,NL,RE,CW,CO,PI
      DIMENSION          WLAY(34,11),TBBY(68),WPATH(68,11)
      COMMON /EM1/ IEMISS,KMAX,ANGLE,LEN,HMIN,IJ,J1,J2,JMIN,JEXTRA,ITYPE
      COMMON /EM2/ IL,IKMAX  ,LENSTOR ,NLL,W(11),E(11)
      COMMON /EM3/ H1,H2,NP1 ,MODEL
       IF(ITYPE.EQ.1) GO TO 2000
      IF (ITYPE.EQ.2.AND.H1.EQ.H2) J2=J1
      IF(H2.GT.H1.AND.ANGLE.GT.90..AND.NP1.EQ.1)  J1=J1-1
      IF(JEXTRA.EQ.1)  J2=J2+1
      IF((ITYPE.EQ.2).AND.(H1.GT.H2).AND.(LENSTOR.EQ.1))J2=J2-1
      IF(ITYPE.EQ.3)  J2=NL
      PRINT 1109, J1,J2
 1109 FORMAT(9I3)
      PRINT 910
 910   FORMAT    (//,20X,* CUMULATIVE ABSORBER AMOUNTS FOR THE  ATMOSPHER
     1IC PATH*,//
     210X,*H2O*,6X,*CO2+*,8X,*O3*,9X,*N2*,8X,*H2O C*,6X,*MOL S*,7X,
     3 *AERO*,6X,*O3 UV*,7X,*H2O C*,7X,*HNO3*,5X,*TAVE*)
      DO 1052 IK=1,68
       TBBY(IK)=0.
      DO 1052 K=1,KMAX
       WPATH(IK,K)=0.
 1052 CONTINUE
      LEN=0
      NLL=NL-1
      IL=J1+1
      IJ=IL+NLL
      DO 1060 K=1,KMAX
      E(K)=0.
 1060 CONTINUE
      IF (ANGLE.GT.90.0) GO TO 1061
      LEN=1.
      IL=J1-1
      HMIN=1.0E-6
      IJ=NLL
 1061 CONTINUE
      DO 1050 IK=1,68
      IF (LEN.EQ.0) IL=IL-1
      IF (LEN.EQ.1) IL=IL+1
      IJ=IJ-1
      IF(IL.EQ.0) GO TO 1050
      DO 1064 K=1,KMAX
      W(K)=E(K)+WLAY(IL,K)
      WPATH(IK,K)=W(K)
 1064 CONTINUE
      IF(IL.LE.0.OR.IL.GE.NL) GO TO 1053
      TBAR=(T(M,IL)+T(M,IL+1))*0.5
C      JEXTRA IS 1 ONLY WHEN PROGRAM NEVER LEAVES ONE LAYER
      IF(JEXTRA.EQ.1)  TBAR=(T(M,J1)+T(M,J1+1))*0.5
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
 1053   CONTINUE                                                          PATH 510   NEW
      TBBY(IK)=TBAR                                                       PATH 520   NEW
      DO 1103 K=1,KMAX                                                    PATH 530   NEW
      F(K)=W(K)                                                           PATH 540   NEW
 1103 CONTINUE                                                            PATH 550   NEW
      IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 1104                         PATH 560   NEW
      IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 1062                        PATH 570   NEW
      IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 1104                PATH 580   NEW
      IF (ITYPE.EQ.2.AND.LENSTOR.EQ.0.AND.IL.EQ.J2) GO TO 1104            PATH 590   NEW
      IF (IL.EQ.JMIN.AND.HMIN.GT.0) LEN=1                                 PATH 600   NEW
      IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 1104                             PATH 610   NEW
      IF (LEN.EQ.0) GO TO 1062                                            PATH 620   NEW
      IF (IL.EQ.JMIN.AND.IJ.EQ.IL+NLL) IL=IL-1                            PATH 630   NEW
      IF (ITYPE.EQ.2.AND.IL.EQ.J2) GO TO 1104                             PATH 640   NEW
 1062 CONTINUE                                                            PATH 650   NEW
      PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 660   NEW
 1050 CONTINUE                                                            PATH 670   NEW
      IKMAX=68                                                            PATH 680   NEW
      LEN=LENSTOR                                                         PATH 690   NEW
       RETURN                                                             PATH 700   NEW
 1104 CONTINUE                                                            PATH 710   NEW
      PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 720   NEW
      IKMAX=IK                                                            PATH 730   NEW
      LEN=LENSTOR                                                         PATH 740   NEW
       RETURN                                                             PATH 750   NEW
 2000 DO 2052 K=1,KMAX                                                    PATH 760   NEW
       WPATH(1,K)=W(K)                                                    PATH 770   NEW
 2052 CONTINUE                                                            PATH 780   NEW
       IF(MODEL.EQ.0) J1=1                                                PATH 790   NEW
       J2=J1                                                              PATH 800   NEW
      TBBY(1)=T(M,J1)                                                     PATH 810   NEW
       IKMAX=1                                                            PATH 820   NEW
      PRINT 1109, J1,J2                                                   PATH 830   NEW
       PRINT 910                                                          PATH 840   NEW
      IK=1                                                                PATH 850   NEW
      PRINT900,IK,(WPATH(IK,K),K=1,8),WPATH(IK,10),WPATH(IK,11),TBBY(IK)PATH 860   NEW
       HMIN=1.0E-6                                                        PATH 870   NEW
      RETURN                                                              PATH 880   NEW
  900 FORMAT(I5,10F11.3,F10.3)                                            PATH 890   NEW
      END                                                                 PATH 900   NEW
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE HNO3 (V,HABS)
      DIMENSION H1(15), H2(16), H3(13)
C ARRAY H1 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM  850 TO 920 CM-1
      DATA H1/2.197,3.911,6.154,8.150,9.217,9.461,11.56,11.10,11.17,12.4
     10,10.49,7.509,6.136,4.899,2.866/
C ARRAY H2 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1275 TO1350 CM-1
      DATA H2/2.828,4.611,6.755,8.759,10.51,13.74,18.00,21.51,23.09,21.6
     18,21.32,16.82,16.42,17.87,14.06,8.716/
C ARRAY H3 CONTAINS HNO3 ABS, COEF(CM-1ATM-1) FROM 1675 TO1735 CM-1
      DATA H3/5.003,8.803,14.12,19.83,23.31,23.58,23.22,21.09,26.99,25.8
     14,24.79,17.68,9.420/
      HABS=0.
      IF (V.GE.850.0.AND.V.LE.920.0) GO TO 1000
      IF (V.GE.1275.0.AND.V.LE.1350.0) GO TO 1001
      IF (V.GE.1675.0.AND.V.LE.1735.0) GO TO 1002
      GO TO 1003
 1000 I=(V-845.)/5.
      HABS=H1(I)
      GO TO 1003
 1001 I=(V-1270.)/5.
      HABS=H2(I)
      GO TO 1003
 1002 I=(V-1670.)/5.
      HABS=H3(I)
 1003 RETURN
      END
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE POINT (X,YN,N,NP,TX,IP)
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,NL,RE,CH,CO,PI
      COMMON /EM1/ IEMTSS,KMAX
      DIMENSION TX(11)
C*********************************************************************
C     SUBROUTINE POINT COMPUTES THE MEAN REFRATIVE INDEX ABOVE AND BELOW
C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
C
C*********************************************************************
C
C      X IS THE HEIGHT IN QUESTION
C      TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
C      N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
C      NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL  ,IF NOT NP = 0
C      TX(1-8) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X
C*********************************************************************
      N=NL
      NP=0
      IF(X.LT.0.0) X=Z(1)
      IF (X.GT.Z(NL)) GO TO 4
      DO 1 I=1,NL
      N=I
      IF (X-Z(I)) 2,4,1
1     CONTINUE
2     J2=N
      N=N-1
      FAC=(X-Z(N))/(Z(J2)-Z(N))
      PX1=P(M,N)*(P(M,J2)/P(M,N))**FAC
      TX1=T(M,N)*(T(M,J2)/T(M,N))**FAC
      WX1=WH(M,N)*(WH(M,J2)/WH(M,N))**FAC
      TX(3)=CO*PX1/TX1-4.56E-6*WX1*TX1*CH
      TX(2)=CO*P(M,J2)/T(M,J2)-4.56E-6*WH(M,J2)*T(M,J2)*CH
      TX(1)=CO*P(M,N)/T(M,N)-4.56E-6*WH(M,N)*T(M,N)*CH
      TX(9)=0.5E-6*(TX(2)+TX(3))
      YN=0.5E-6*(TX(1)+TX(3))
      IF (IP.EQ.0) GO TO 9
      DO 3 K=1,KMAX
      IF(K.EQ.9) GO TO 3
       TX(K)=0.0
      IF (EH(K,N).EQ.0.0) GO TO 3
      IF (EH(K,N).GT.1000.0) GO TO 3
      TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC
3     CONTINUE
      GO TO 9
4     NP=1
      IF (IP.EQ.0) GO TO 6
      DO 5 K=1,KMAX
5     TX(K)=EH(K,N)
6     TX(9)=EH(9,N)-1.
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      YN=0.0                                                            POIN 510     B  48
C*****  CARDS B 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED             POIN 520     B  48+
      IF (N.GT.1) YN=EH(9,N-1)-1.0                                      POIN 530     B  49
9     CONTINUE                                                          POIN 540     B  60
      IF (IP.EQ.1) PRINT 400, X,N,NP,TX(9),YN,IP,(TX(K),K=1,8)          POIN 550     B  61
      TX(9)=TX(9)+1.                                                    POIN 560     B  62
      YN=YN+1.                                                          POIN 570     B  63
      RETURN                                                            POIN 580     B  64
C                                                                       POIN 590     B  65
400   FORMAT (/,* FROM POINT! HEIGHT=*,F10.4,* KM,N=*,I3,*,NF=*,I2,*,REFPOIN 600     B  66
     1. INDEX ABOVE & BELOW X=*,2F11.4,*,IP=*,I3,/,12X,*EQUIV. ABSORBER POIN 610     B  67
     2AMOUNTS PER KM AT X=*,8F10.3)                                     POIN 620     B  68
      END                                                               POIN 630     B  69
```

Table A1 Listing of Fortran Code LOWTRAN 4 (Cont)

```
      SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,ML)
      COMMON Z(34),P(7,34),T(7,34),EH(11,34),WH(7,34),M,NL,RE,CW,CO,PI
      COMMON /EM1/ IEMISS,KMAX
      DIMENSION TX(11)
C*********************************************************************
C
C     THIS SUBROUTINE CALCULATES THE INITIAL ZENITH ANGLE (ANGLE)
C     TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
C     (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
C     ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
C     FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
C     ATMOSPHERE.
C
C     THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
C*********************************************************************
      IP=99
      CA=PI/180.
      X1=RE+H1
      X2=RE+H2
      LEN=0.
      IT=0
      B1=B1*CA

      TANG=X2*SIN(B1)/(X2*COS(B1)-X1)
      THET=ATAN(TANG)
      IF (THET.LT.0.0) THET=THET+PI
      SPHI=SIN(THET)
      ANG=THET/CA
C     PRINT 404, B1,ANG,TANG
      TN=THET
      TM=TN-0.5*CA
1     ANGLE=THET
      EBT=0.
      BETA=0.
      BET1=0
      BET2=0
      EBT1=0
      EBT2=0
      EBT3=0.0
      IF(B1.LE.0.0) GO TO 2
C     PRINT 400, IT
      Y=2.*THET
      IF (Y-PI.GT.1.0E-8) GO TO 9
      IF (IP.EQ.100) GO TO 6
      XMIN=X2*COS(B1)-RE
      IF (XMIN-H1) 8,4,4
2     HMIN=H2
      H2=H1
      H1=HMIN
3     ANGLE=0.5*PI
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      THET=ANGLE
      SPHI=1.0
      ANG=ANGLE/CA
C     PRINT 404, B1,ANG,SPHI
4     IP=100
      CALL POINT (H1,YN,N,NP,TX,IP)
      J1=N
      TX1=TX(9)
5     CALL POINT (H2,YN,N,NP,TX,IP)
      IF (NP.EQ.1) N=N-1
      J2=N
      IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
6     DO 7 J=J1,J2
      X1=RE+Z(J)
      X2=RE+Z(J+1)
      IF (J.EQ.J1) X1=RE+H1
      IF (J.EQ.J2) X2=RE+H2
      SALP=X1*SPHI/X2
      ALP=ASIN(SALP)
      RN=EH(9,J+1)/EH(9,J)
      IF ((J+1).EQ.J2) RN=YN/EH(9,J)
      IF (J.EQ.J1) RN=EH(9,J+1)/TX1
      IF ((J+1).EQ.J2.AND.J.EQ.J1) RN=YN/TX1
      BET=THET-ALP
      FB=-TAN(ALP)
      IF (J.NE.J1) FB=FB+TAN(THET)
      FBT=FBT+FB
      BETA=BETA+BET
      TH1=THET/CA
      BE=BET/CA
      C=ALP/CA
C     PRINT 402, J,Z(J),THET,ALP,BET,BETA,FBT,FB,TH1,BE,C
      IF (X2.EQ.RE+H2) C=PI-ALP
      IF (SALP.GE.RN) RN=1.
      SPHI=SALP/RN
      THET=ASIN(SPHI)
7     CONTINUE
      IF(B1.LE.0.0) GO TO 29
      GO TO 26
8     CONTINUE
      TANG=-TANG
      ANGLE=PI-ANGLE
      TN=ANGLE
      ANG=ANGLE/CA
C     PRINT 404, B1,ANG,TANG
      IF (H1.LE.0.0) GO TO 3
9     CONTINUE
      IP=101
      CALL POINT (H1,YN,N,NP1,TX,IP)
      TX1=TX(9)
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      YN1=YN                                                          ANGL1010   C  94
      IF (NP1.EQ.1) N=N-1                                             ANGL1020   C  95
      J2=NL                                                           ANGL1030   C  96A
      IF (M.EQ.7) J2=ML                                               ANGL1040   C  96B
      J1=N                                                            ANGL1050   C  97
      J=J1+1                                                          ANGL1060   C  98
      IF (H2.GE.H1) GO TO 13                                          ANGL1070   C  99
      CALL POINT (H2,YN,N,NF,TX,IP)                                   ANGL1080   C 100
      TX2=TX(9)                                                       ANGL1090   C 101
      YN2=YN                                                          ANGL1100   C 102
      J2=N                                                            ANGL1110   C 103
      IF (J1.EQ.J2) TX2=YN1+TX(9)-FH(9,J1)                            ANGL1120   C 104
10    J=J-1                                                           ANGL1130   C 105
      X1=RE+Z(J+1)                                                    ANGL1140   C 106
      X2=RE+Z(J)                                                      ANGL1150   C 107
      IF (J.EQ.J1) X1=RE+H1                                           ANGL1160   C 108
      IF (J.EQ.J2) X2=RE+H2                                           ANGL1170   C 109
      SALP=X1*SPHI/X2                                                 ANGL1180   C 110
      HMIN=X1*SPHI-RE                                                 ANGL1190   C 111
C     PRINT 402, J,X1,Z(J),SPHI,SALP,HMIN,RE                          ANGL1200   C 112
      IF (SALP.LE.1.0) GO TO 11                                       ANGL1210   C 113
      SALP=SPHI                                                       ANGL1220   C 114
      IF (HMIN.GT.H2) GO TO 18                                        ANGL1230   C 115
11    ALP=ASIN(SALP)                                                  ANGL1240   C 116
      THET=ASIN(SPHI)                                                 ANGL1250   C 117
      BET=ALP-THET                                                    ANGL1260   C 118
      BET1=BET1+BET                                                   ANGL1270   C 119
      FB=TAN(ALP)                                                     ANGL1280   C 120
      IF (J.NE.J1) FB=FB-TAN(THET)                                    ANGL1290   C 121
      FBT1=FBT1+FB                                                    ANGL1300   C 122
      TH1=THET/CA                                                     ANGL1310   C 123
      BE=BET/CA                                                       ANGL1320   C 124
      AL=ALP/CA                                                       ANGL1330   C 125
C     PRINT 402, J,X2,THET,ALP,BET1,BET,BMIN,HMIN,FBT1,TH1,BE,AL      ANGL1340   C 126
      IF (X2.EQ.RE+H2) G=FI-ALP                                       ANGL1350   C 127
      REF=FH(9,J)                                                     ANGL1360   C 128
      IF (J.EQ.J1) REF=YN1                                            ANGL1370   C 129
      IF (J.EQ.J2) REF=TX2                                            ANGL1380   C 130
      IF (J.EQ.1) GO TO 12                                            ANGL1390   C 131
      RN=FH(9,J)/FH(9,J-1)                                            ANGL1400   C 132
      IF (J.EQ.J1) RN=YN1/FH(9,J-1)                                   ANGL1410   C 133A
      IF(J.EQ.J2+1) RN=REF/TX2                                        ANGL1420   C 133B
      IF(J.EQ.J2) RN=REF/YN2                                          ANGL1430   C 133C
      IF (SALP.GT.RN) RN=1.                                           ANGL1440   C 134
      SPHI=SALP*RN                                                    ANGL1450   C 135
      IF (Z(J).LE.H2) GO TO 12                                        ANGL1460   C 136
      GO TO 10                                                        ANGL1470   C 137
12    X1=X2                                                           ANGL1480   C 138
      IF (ABS(Z(J)-H2).LT.1.0E-10.AND.J.NE.1) GO TO 13                ANGL1490   C 139
      GO TO 14                                                        ANGL1500   C 140
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
13     J=J-1
       X1=RE+Z(J+1)
       IF (J.EQ.J1) X1=RE+H1
       IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2
14     X2=RE+Z(J)
       HMIN=X1*SPHI-RE
       IF (HMIN.LE.0.0) GO TO 25
       IF (Z(J).LT.HMIN) GO TO 18
       REF=EH(9,J)
       IF (J.EQ.J2) REF=YN
       SALP=X1*SPHI/X2
       ALP=ASIN(SALP)
       THET=ASIN(SPHI)
       BET=ALP-THET
       FB=TAN(ALP)-TAN(THET)
       FBT2=FBT2+FB
       BET2=BET2+BET
       BMIN=BET1+BET2
       AL=ALP/CA
       TH1=THET/CA
C      PRINT 402, J,X2,THET,ALP,BET2,BET,BMIN,HMIN,FBT2,TH1,BF,AL
       RN=REF/EH(9,J-1)
       IF (SALP.GE.RN) RN=1.0
       SPHI=SALP*RN
       GO TO 13
17     TX3=YN1+TX(9)-EH(9,J1)
       YN1=TX3
       IF (ABS(H2-Z(J+1)).LE.1.0E-5) YN1=TX(9)
       IF (ABS(H1-Z(J+1)).LE.1.0E-5) YN1=TX(9)
       RN=1.0
       GO TO 19
18     CALL POINT (HMIN,YN,N,NP,TX,IP)
       IP=102
       TX3=TX(9)
       IF (J.EQ.J1.AND.H2.GE.H1) GO TO 17
       IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX(9)-EH(9,J)
       IF (HMIN.GT.H2) TX3=TX(9)
       IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17
       RN=REF/TX3
       IF (SALP.GE.RN) RN=1.
       SPHI=SALP*RN
       X=X1*SPHI-RE
       DIF=ABS(HMIN-X)
       HMIN=X
       IF (DIF-1.0E-5) 19,19,18
19     X2=RE+HMIN
C      PRINT 403, HMIN,DIF,RN
       THET=ASIN(SPHI)
       IF(RN.EQ.1.0) FBT3=-TAN(THET)
       IF (RN.EQ.1) GO TO 20
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      DNX=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)                    ANGL2010  C 190
      FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*DNX)))                       ANGL2020  C 191
20    BET=0.5*PI-THET                                                    ANGL2030  C 192
      BET2=BET2+BET                                                      ANGL2040  C 193
      BMIN=BET1+BET2                                                     ANGL2050  C 194
      IF (H2.GE.H1) GO TO 23                                             ANGL2060  C 195
      BET=BET1+2.*BET2                                                   ANGL2070  C 196
      DB1=B1-BET1                                                        ANGL2080  C 197
      DB2=BET-B1                                                         ANGL2090  C 198
21      DB3=ABS(BMIN-B1)                                                 ANGL2100  C 199A
      IF(DB3.GT.DB1.AND.DB2.GT.DB1) GO TO 25                             ANGL2110  C 199B
      IF(DB2.GT.DB3) GO TO 22                                            ANGL2120  C 199C
      IF(DB2.GT.DB1)   GO TO 25                                          ANGL2130  C 200
      BETA=BET                                                           ANGL2140  C 201
      FBT=FBT1+2.0*(FBT2+FBT3)                                           ANGL2150  C 202
      LEN=1.                                                             ANGL2160  C 203
      GO TO 26                                                           ANGL2170  C 204
22    BETA=BET1+BET2                                                     ANGL2180  C 205
      FBT=FBT1+FBT2+FBT3                                                 ANGL2190  C 206
C     PRINT 401, J,BET ,FBT,FBT1,FBT2,FBT3,TX1,YN1                       ANGL2200  C 207
      GO TO 26                                                           ANGL2210  C 208
23    BETA=2.0*(BET1+BET2)                                               ANGL2220  C 209
      LEN=1.                                                             ANGL2230  C 210
      FBT=2.0*(FBT1+FBT2+FBT3)                                           ANGL2240  C 211
      PRINT 401, J,BETA,FBT,FBT1,FBT2,FBT3,TX1,YN1                       ANGL2250  C 212
      IF (H2.EQ.H1) GO TO 26                                             ANGL2260  C 213
      IP=103                                                             ANGL2270  C 214
      IF (NP1.EQ.1) J1=J1+1                                              ANGL2280  C 215
      SPHI=SIN(ANGLE)                                                    ANGL2290  C 216
      IF (Z(J1+1).LE.H2) GO TO 24                                        ANGL2300  C 217
      RN=TX1/YN1                                                         ANGL2310  C 218
      IF (SPHI.GE.RN) RN=1.                                              ANGL2320  C 219
      SPHI=SPHI/RN                                                       ANGL2330  C 220
      THET=ASIN(SPHI)                                                    ANGL2340  C 221
      GO TO 5                                                            ANGL2350  C 222
24    CALL POINT (H2,YN,N,NP,TX,IP)                                      ANGL2360  C 223
      TX1=TX1+YN-EH(9,J1)                                                ANGL2370  C 224
      RN=TX1/YN1                                                         ANGL2380  C 225
      J2=J1                                                              ANGL2390  C 226
      IF (SPHI.GE.RN) RN=1.                                              ANGL2400  C 227
      SPHI=SPHI/RN                                                       ANGL2410  C 228
      THET=ASIN(SPHI)                                                    ANGL2420  C 229
      GO TO 5                                                            ANGL2430  C 230
25    BETA=BET1                                                          ANGL2440  C 231
      LEN=0.                                                             ANGL2450  C 232
      FBT=FBT1                                                           ANGL2460  C 233
26    THET=ANGLE+(B1-BETA)/(1.+FBT/TANG)                                 ANGL2470  C 234
      DBETA=BETA/CA                                                      ANGL2480  C 235
      B=BET1/CA                                                          ANGL2490  C 236
      TH1=THET/CA                                                        ANGL2500  C 237
```

Table A1. Listing of Fortran Code LOWTRAN 4 (Cont)

```
      PRINT 404, BETA,OBETA,FBT,TH1,TANG                                ANGL2510   C 238
      IF (THET.GT.TN.OR.THET.LT.TM) THET=(TN+TM)/2.                     ANGL2520   C 239
      TH1=THET/CA                                                       ANGL2530   C 240*
      PRINT 404, BET1,B,FBT,TH1                                         ANGL2540   C 241*
      TN1=TN/CA                                                         ANGL2550   C 242
      TM1=TM/CA                                                         ANGL2560   C 243
      PRINT 405, TN,TM,TN1,TM1                                          ANGL2570   C 244
      SPHI=SIN(THET)                                                    ANGL2580   C 245
      TANG=TAN(THET)                                                    ANGL2590   C 246
      IT=IT+1                                                           ANGL2600   C 247
      DBE=ABS(B1-BETA)                                                  ANGL2610   C 248
      DTH=ABS(ANGLE-THET)                                               ANGL2620   C 249
      IF (IT.EQ.10)  THET=0.5*(ANGLE+THET)                              ANGL2630   C 250*
      IF (IT.EQ.10) GO TO 28                                            ANGL2640   C 251
      IF (DBE.GT.1.0E-7.AND.DTH.GT.1.0E-7) GO TO 1                      ANGL2650   C 252
28    ANGLE=THET/CA                                                     ANGL2660   C 253
      PRINT 406, ANGLE,IT                                               ANGL2670   C 254
      RETURN                                                            ANGL2680   C 255A
29    H1=H2                                                             ANGL2690   C 255B
      ANGLE=C/CA                                                        ANGL2700   C 255C
      PRINT 406, ANGLE,IT                                               ANGL2710   C 255D
      RETURN                                                            ANGL2720   C 255E
C                                                                       ANGL2730   C 256
400   FORMAT (//* ITTERATION NUMBER *,I3,//)                            ANGL2740   C 257
401   FORMAT (I6,E16.7,8F13.8)                                          ANGL2750   C 258
402   FORMAT (I4,F10.4,6E13.4,4F10.4/)                                  ANGL2760   C 259
403   FORMAT (*  HMIN=*,F14.6,*  DIF=*F14.6,*  PR=*,E16.8)              ANGL2770   C 260
404   FORMAT (* TOTAL BETA = *,E14.6,F15.6,*,FBT = *,E14.6,* THET =*,F1ANGL2780   C 261
     1.6,*TANG=*,F10.6)                                                 ANGL2790   C 262
405   FORMAT (5F12.6)                                                   ANGL2800   C 263
406   FORMAT (8X,/1H*,*ZENITH ANGLE =*,F7.3,* DEGREES     RECOMPUTED    ANGL2810   C 264
     1 FROM SUBROUTINE ANGL (ITTERATION*,I3,*)*)                        ANGL2820   C 265
      END                                                               ANGL2830   C 266
```

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A2. Listing of Data for LOWTRAN 4

```
 6 34
2.830E+03 1.245E+03 5.374E+02 2.257E+02 1.193E+02 8.992E+01 6.341E+01 5.893E+01
6.073E+01 5.822E+01 5.679E+01 5.320E+01 5.589E+01 5.159E+01 5.052E+01 4.747E+01
4.514E+01 4.460E+01 4.317E+01 3.636E+01 2.669E+01 1.935E+01 1.456E+01 1.114E+01
8.831E+00 7.434E+00 2.239E+00 5.893E-01 1.551E-01 4.084E-02 1.078E-02 5.553E-05
1.970E-08-0.
1.379E+04 5.034E+03 1.845E+03 6.735E+02 2.454E+02
   0.0 1.013E+03 300.0    1.9E 01     5.6E-05 1.013E+03 294.0     1.4E 01     6.0E-05
   1.0 9.040E+02 294.0    1.3E+01     5.6E-05 9.020E+02 290.0     5.3E+00     6.0E-05
   2.0 8.050E+02 288.0    9.3E+00     5.4E-05 8.020E+02 285.0     5.9E+00     6.5E-05
   3.0 7.150E+02 284.0    4.7E+00     5.1E-05 7.100E+02 279.0     3.3E+00     5.2E-05
   4.0 6.330E+02 277.0    2.2E+00     4.7E-05 6.280E+02 273.0     1.9E+00     6.4E-05
   5.0 5.590E+02 270.0    1.5E+00     4.5E-05 5.540E+02 267.0     1.0E+00     6.6E-05
   6.0 4.920E+02 264.0    8.5E-01     4.3E-05 4.870E+02 261.0     6.1E-01     6.9E-05
   7.0 4.320E+02 257.0    4.7E-01     4.1E-05 4.260E+02 255.0     3.7E-01     7.5E-05
   8.0 3.780E+02 250.0    2.5E-01     3.9E-05 3.720E+02 248.0     2.1E-01     7.9E-05
   9.0 3.290E+02 244.0    1.2E-01     3.9E-05 3.240E+02 242.0     1.2E-01     9.6E-05
  10.0 2.860E+02 237.0    5.0E-02     3.9E-05 2.810E+02 235.0     6.4E-02     [illegible]E-05
  11.0 2.470E+02 230.0    1.7E-02     4.1E-05 2.430E+02 229.0     2.2E-02     1.1E-04
  12.0 2.130E+02 224.0    6.0E-03     4.3E-05 2.090E+02 222.0     6.0E-03     1.2E-04
  13.0 1.820E+02 217.0    1.8E-03     4.5E-05 1.790E+02 216.0     1.8E-03     1.5E-04
  14.0 1.560E+02 210.0    1.0E-03     4.5E-05 1.530E+02 216.0     1.0E-03     1.8E-04
  15.0 1.320E+02 204.0    7.6E-04     4.7E-05 1.300E+02 216.0     7.6E-04     1.9E-04
  16.0 1.110E+02 197.0    6.4E-04     4.7E-05 1.110E+02 216.0     6.4E-04     2.1E-04
  17.0 9.370E+01 195.0    5.6E-04     6.9E-05 9.500E+01 216.0     5.6E-04     2.4E-04
  18.0 7.890E+01 199.0    5.0E-04     9.0E-05 8.120E+01 216.0     5.0E-04     2.8E-04
  19.0 6.660E+01 203.0    4.9E-04     1.4E-04 6.950E+01 217.0     4.9E-04     3.2E-04
  20.0 5.650E+01 207.0    4.5E-04     1.9E-04 5.950E+01 218.0     4.5E-04     3.4E-04
  21.0 4.800E+01 211.0    5.1E-04     2.4E-04 5.100E+01 219.0     5.1E-04     3.6E-04
  22.0 4.090E+01 215.0    5.1E-04     2.8E-04 4.370E+01 220.0     5.1E-04     3.6E-04
  23.0 3.500E+01 217.0    5.4E-04     3.2E-04 3.760E+01 222.0     5.4E-04     3.4E-04
  24.0 3.000E+01 219.0    6.0E-04     3.4E-04 3.220E+01 223.0     6.0E-04     3.2E-04
  25.0 2.570E+01 221.0    6.7E-04     3.4E-04 2.770E+01 224.0     6.7E-04     3.0E-04
  30.0 1.220E+01 232.0    3.6E-04     2.4E-04 1.320E+01 234.0     3.6E-04     2.0E-04
  35.0 6.000E+00 243.0    1.1E-04     9.2E-05 6.520E+00 245.0     1.1E-04     9.2E-05
  40.0 3.050E+00 254.0    4.3E-05     4.1E-05 3.330E+00 258.0     4.3E-05     4.1E-05
  45.0 1.590E+00 265.0    1.9E-05     1.3E-05 1.760E+00 270.0     1.9E-05     1.3E-05
  50.0 8.540E-01 270.0    6.3E-06     4.3E-06 9.510E-01 276.0     6.3E-06     4.3E-06
  70.0 5.790E-02 219.0    1.4E-07     8.6E-08 6.710E-02 218.0     1.4E-07     8.6E-08
 100.0 3.000E-04 210.0    1.0E-09     4.3E-11 3.000E-04 210.0     1.0E-09     4.3E-11
99999. 0.000E+00 210.     0.0E-00     0.0E-00 0.000E 00 210.0     0.0E-00     0.0E-00
   0.0 1.018E+03 272.2    3.5E+00     6.0E-05 1.010E+03 287.0     9.1E+00     4.9E-05
   1.0 8.973E+02 268.7    2.5E+00     5.4E-05 8.960E+02 282.0     6.0E+00     5.4E-05
   2.0 7.897E+02 265.2    1.8E+00     4.9E-05 7.929E+02 276.0     4.2E+00     5.6E-05
   3.0 6.938E+02 261.7    1.2E+00     4.9E-05 7.000E+02 271.0     2.7E+00     5.8E-05
   4.0 6.081E+02 255.7    6.6E-01     4.9E-05 6.160E+02 266.0     1.7E+00     6.0E-05
   5.0 5.313E+02 249.7    3.8E-01     5.8E-05 5.410E+02 260.0     1.0E+00     6.4E-05
   6.0 4.627E+02 243.7    2.1E-01     6.4E-05 4.730E+02 253.0     5.4E-01     7.1E-05
   7.0 4.016E+02 237.7    8.5E-02     7.7E-05 4.130E+02 246.0     2.9E-01     7.5E-05
   8.0 3.473E+02 231.7    3.5E-02     9.0E-05 3.590E+02 239.0     1.3E-01     7.9E-05
```

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A2. Listing of Data for LOWTRAN 4 (Cont)

MODEL ATMOSPHERES 3 & 4 CONT'D

9.0	2.992E+02	225.7	1.6E-02	1.2E-04	3.107E+02	232.0	4.2E-02	1.1E-04
10.0	2.568E+02	219.7	7.5E-03	1.6E-04	2.677E+02	225.0	1.5E-02	1.3E-04
11.0	2.199E+02	219.2	6.9E-03	2.1E-04	2.300E+02	225.0	9.4E-03	1.8E-04
12.0	1.882E+02	218.7	6.0E-03	2.6E-04	1.977E+02	225.0	6.0E-03	2.1E-04
13.0	1.610E+02	218.2	1.8E-03	3.0E-04	1.700E+02	225.0	1.6E-03	2.6E-04
14.0	1.378E+02	217.7	1.0E-03	3.2E-04	1.460E+02	225.0	1.0E-03	2.8E-04
15.0	1.178E+02	217.2	7.6E-04	3.4E-04	1.250E+02	225.0	7.6E-04	3.2E-04
16.0	1.007E+02	216.7	6.4E-04	3.6E-04	1.080E+02	225.0	6.4E-04	3.4E-04
17.0	8.610E+01	216.2	5.6E-04	3.9E-04	9.280E+01	225.0	5.6E-04	3.9E-04
18.0	7.350E+01	215.7	5.0E-04	4.1E-04	7.980E+01	225.0	5.0E-04	4.1E-04
19.0	6.280E+01	215.2	4.9E-04	4.3E-04	6.860E+01	225.0	4.9E-04	4.1E-04
20.0	5.370E+01	215.2	4.5E-04	4.5E-04	5.890E+01	225.0	4.5E-04	3.9E-04
21.0	4.580E+01	215.2	5.1E-04	4.3E-04	5.070E+01	225.0	5.1E-04	3.6E-04
22.0	3.910E+01	215.2	5.1E-04	4.3E-04	4.360E+01	225.0	5.1E-04	3.2E-04
23.0	3.340E+01	215.2	5.4E-04	3.9E-04	3.750E+01	225.0	5.4E-04	3.0E-04
24.0	2.860E+01	215.2	6.0E-04	3.6E-04	3.227E+01	226.0	6.0E-04	2.8E-04
25.0	2.430E+01	215.2	6.7E-04	3.4E-04	2.760E+01	228.0	6.7E-04	2.6E-04
30.0	1.110E+01	217.4	3.6E-04	1.9E-04	1.340E+01	235.0	3.6E-04	1.4E-04
35.0	5.180E+00	227.8	1.1E-04	9.2E-05	6.610E+00	247.0	1.1E-04	9.2E-05
40.0	2.530E+00	243.2	4.3E-05	4.1E-05	3.400E+00	262.0	4.3E-05	4.1E-05
45.0	1.290E+00	258.5	1.9E-05	1.3E-05	1.810E+00	274.0	1.9E-05	1.3E-05
50.0	6.820E-01	265.7	6.3E-06	4.3E-06	9.870E-01	277.0	6.3E-06	4.3E-06
70.0	4.670E-02	230.7	1.4E-07	8.6E-08	7.070E-02	216.0	1.4E-07	8.6E-08
100.0	3.000E-04	210.2	1.0E-09	4.3E-11	3.000E-04	210.0	1.0E-09	4.3E-11
99999.	0.000E+00	210.	0.0E-00	0.0E-00	0.000E 00	210.0	0.0E-00	0.0E-00
0.0	1.013E+03	257.1	1.2E+00	4.1E-05	1.013E+03	288.1	5.9E+00	5.4E-05
1.0	8.878E+02	259.1	1.2E+00	4.1E-05	8.986E+02	281.6	4.2E+00	5.4E-05
2.0	7.775E+02	255.9	9.4E-01	4.1E-05	7.950E+02	275.1	2.9E+00	5.4E-05
3.0	6.798E+02	252.7	6.8E-01	4.3E-05	7.012E+02	268.7	1.8E+00	5.0E-05
4.0	5.932E+02	247.7	4.1E-01	4.5E-05	6.166E+02	262.2	1.1E+00	4.6E-05
5.0	5.158E+02	240.9	2.0E-01	4.7E-05	5.405E+02	255.7	6.4E-01	4.6E-05
6.0	4.467E+02	234.1	9.8E-02	4.9E-05	4.722E+02	249.2	3.8E-01	4.5E-05
7.0	3.853E+02	227.3	5.4E-02	7.1E-05	4.111E+02	242.7	2.1E-01	4.9E-05
8.0	3.308E+02	220.6	1.1E-02	9.0E-05	3.565E+02	236.2	1.2E-01	5.2E-05
9.0	2.829E+02	217.2	8.4E-03	1.6E-04	3.080E+02	229.7	4.6E-02	7.1E-05
10.0	2.418E+02	217.2	5.5E-03	2.4E-04	2.650E+02	223.2	1.8E-02	9.0E-05
11.0	2.067E+02	217.2	3.8E-03	3.2E-04	2.270E+02	216.8	8.2E-03	1.3E-04
12.0	1.766E+02	217.2	2.6E-03	4.3E-04	1.940E+02	216.6	3.7E-03	1.6E-04
13.0	1.510E+02	217.2	1.8E-03	4.7E-04	1.658E+02	216.6	1.8E-03	1.7E-04
14.0	1.291E+02	217.2	1.0E-03	4.9E-04	1.417E+02	216.6	8.4E-04	1.9E-04
15.0	1.103E+02	217.2	7.6E-04	5.6E-04	1.211E+02	216.6	7.2E-04	2.1E-04
16.0	9.431E+01	216.6	6.4E-04	6.2E-04	1.035E+02	216.6	6.1E-04	2.4E-04
17.0	8.058E+01	216.0	5.6E-04	6.2E-04	8.850E+01	216.6	5.2E-04	2.8E-04
18.0	6.882E+01	215.4	5.0E-04	6.2E-04	7.565E+01	216.6	4.4E-04	3.2E-04
19.0	5.875E+01	214.8	4.9E-04	6.0E-04	6.467E+01	216.6	4.4E-04	3.5E-04
20.0	5.014E+01	214.1	4.5E-04	5.6E-04	5.529E+01	216.6	4.4E-04	3.8E-04
21.0	4.277E+01	213.6	5.1E-04	5.1E-04	4.729E+01	217.6	4.8E-04	3.8E-04
22.0	3.647E+01	213.0	5.1E-04	4.7E-04	4.047E+01	218.6	5.2E-04	3.9E-04
23.0	3.109E+01	212.4	5.4E-04	4.3E-04	3.467E+01	219.6	5.7E-04	3.8E-04
24.0	2.649E+01	211.8	6.0E-04	3.6E-04	2.972E+01	220.6	6.1E-04	3.6E-04

MODEL ATMOSPHERES 5 & 6

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
  25.0 2.2 6E+01 211.2     6.7E-04     3.2E-04 2.549E+01 221.6     6.6E-04     3.4E-04
  30.0 1.0 0E+01 216.0     3.6E-04     1.5E-04 1.197E+01 226.5     3.8E-04     2.0E-04
  35.0 4.701E+00 222.2     1.1E-04     9.2E-05 5.746E+00 236.5     1.6E-04     1.1E-04
  40.0 2.243E+00 234.7     4.3E-05     4.1E-05 2.871E+00 253.4     6.7E-05     4.9E-05
  45.0 1.113E+00 247.0     1.9E-05     1.3E-05 1.491E+00 264.2     3.2E-05     1.7E-05
  50.0 5.719E-01 259.3     6.3E-06     4.3E-06 7.978E-01 270.6     1.2E-05     4.0E-06
  70.0 4.016E-02 245.7     1.4E-07     8.6E-08 5.520E-02 219.7     1.5E-07     8.6E-08
 100.0 3.000E-04 210.0     1.0E-09     4.3E-11 3.008E-04 210.0     1.0E-09     4.3E-11
99999. 0.000E+00 210.      0.0E-00     0.0E-00 0.000E 00 210.0     0.0E-00     0.0E-00
  .200 .38223 .07945  .250 .32 7  .03661   .300 .28540 .02110   .400 .22026 .01317
  .488 .17989 .01114  .550 .15800 .01095   .694 .12064 .00968   .860 .09151 .01058
 1.060 .07078 .01070 1.536 .04184 .00933 1.800 .03126 .00700 2.000 .02510 .00437
 2.500 .02068 .00463 3.000 .01900 .00584 3.500 .01767 .00250 3.750 .01699 .00214
 4.000 .01654 .00232 5.000 .01533 .00321 5.500 .01479 .00388 6.000 .01389 .00462
 7.200 .01569 .00745 7.900 .01102 .00617 8.200 .01019 .00807 8.500 .01778 .01254
 8.700 .01994 .01126 9.000 .02112 .01209 9.200 .02213 .01378 9.500 .01870 .01005
  9.80 .01744 .00832 10.00 .01714 .00810 10.59 .01588 .00686 11.00 .01514 .00570
 11.50 .01455 .00535 12.50 .01365 .00516 13.00 .01339 .00523 14.00 .01286 .00538
 15.00 .01368 .00834 16.40 .01384 .00696 17.20 .01480 .00767 18.50 .01353 .00677
 20.00 .01427 .00767 22.50 .01381 .00767 25.00 .01302 .00749 30.00 .01204 .00761
 0.999-2.3468-1.6776 0.998-2.0362-1.3960 0.996-1.6990-1.1192 0.994-1.4815-0.9508
 0.992-1.3279-0.8239 0.990-1.2007-0.7258 0.980-0.7825-0.4318 0.970-0.5229-0.2366
 0.960-0.3468-0.1074 0.950-0.1938-0.        0.940-0.0655 0.0969 0.930 0.0414 0.1761
 0.920 0.1553 0.2304 0.910 0.2430 0.3010 0.900 0.3324 0.3522 0.880 0.4342 0.4624
 0.860 0.6128 0.5563 0.840 0.7243 0.6435 0.820 0.8261 0.7243 0.800 0.9191 0.7924
 0.780 1.0000 0.8573 0.760 1.0792 0.9191 0.740 1.1461 0.9731 0.720 1.2122 1.0253
 0.700 1.2672 1.0719 0.680 1.3284 1.1173 0.660 1.3892 1.1614 0.640 1.4409 1.2095
 0.620 1.4955 1.2480 0.600 1.5441 1.2900 0.580 1.5966 1.3263 0.560 1.6435 1.3617
 0.540 1.6857 1.3979 0.520 1.7340 1.4393 0.500 1.7782 1.4698 0.480 1.8261 1.4983
 0.460 1.8692 1.5314 0.440 1.9191 1.5682 0.420 1.9538 1.6021 0.400 2.0186 1.6335
 0.380 2.0607 1.6721 0.360 2.1038 1.7076 0.340 2.1461 1.7482 0.320 2.1675 1.7924
 0.300 2.2304 1.8325 0.280 2.2788 1.8865 0.260 2.3263 1.9395 0.240 2.3717 2.0000
 0.220 2.4183 2.0607 0.200 2.4698 2.1206 0.180 2.5159 2.1903 0.160 2.5740 2.2552
 0.140 2.6284 2.3385 0.120 2.6902 2.4313 0.100 2.7559 2.5195 0.080 2.8261 2.6435
 0.060 2.9031 2.7853 0.040 3.0000 2.9777 0.030 3.0607 3.1072 0.020 3.1461 3.2553
 0.015 3.2041 3.3617 0.010 3.2718 3.4771 0.008 3.3054 3.5563 0.006 3.3444 3.6233
 0.004 3.3979 3.7076 0.002 3.4914 3.8325 0.001 3.5682 3.9345
 3.93 3.72 3.54 3.42 3.37 3.37 3.36 3.33 3.25 3.13 3.02 2.96 2.97 3.00 3.08  350
 3.12 3.08 3.03 3.00 3.01 3.03 3.07 3.05 3.01 2.94 2.83 2.71 2.62 2.58 2.57  425
 2.62 2.67 2.72 2.71 2.60 2.46 2.35 2.26 2.22 2.23 2.19 2.17 2.17 2.20 2.26  500
 2.34 2.42 2.39 2.26 2.01 1.92 1.83 1.78 1.73 1.81 1.84 1.83 1.80 1.71 1.51  575
 1.39 1.30 1.25 1.18 1.19 1.18 1.21 1.33 1.47 1.53 1.54 1.36 1.12 0.89 0.69  650
 0.49 0.60 0.71 0.79 0.99 0.86 0.73 0.53 0.43 0.51 0.52 0.67 0.73 0.80 0.83  725
 0.80 0.63 0.47 0.32-0.08-0.21-0.29-0.21-0.01 0.08 0.16 0.09-0.03-0.21-0.37  800
-0.35-0.30-0.31-0.37-0.42-0.48-0.42-0.40-0.39-0.43-0.77-0.83-0.83-0.79-0.60  875
-0.50-0.42-0.39-0.38-0.37-0.40-0.51-0.67-0.82-0.58-0.40-0.32-0.21-0.09-0.18  950
-0.16-0.19-0.26-0.33-0.35-0.28-0.22-0.10-0.05-0.11-0.13-0.27-0.27-0.18-0.06 1025
 0.11 0.23 0.26 0.19 0.11-0.00-0.09 0.02 0.08 0.12 0.22 0.28 0.39 0.54 0.68 1100
 0.75 0.79 0.79 0.71 0.69 0.76 0.88 1.01 1.16 1.18 1.14 1.05 1.02 1.11 1.23 1175
 1.41 1.75 1.83 1.99 2.05 2.03 2.00 1.96 1.90 1.86 1.91 2.08 2.24 2.41 2.63 1250
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

2.68	2.67	2.73	2.79	2.81	2.91	2.93	3.02	3.16	3.23	3.30	3.34	3.43	3.57	3.59	1325
3.59	3.58	3.57	3.61	3.71	3.71	3.69	3.64	3.60	3.68	3.80	3.95	4.05	4.05	4.02	1400
3.99	3.96	4.01	4.13	4.22	4.35	4.49	4.58	4.62	4.63	4.61	4.57	4.56	4.56	4.53	1475
4.49	4.46	4.40	4.28	4.14	3.92	3.63	3.35	3.16	3.10	3.24	3.47	3.66	3.80	3.93	1550
4.00	4.04	4.15	4.23	4.31	4.35	4.31	4.23	4.20	4.24	4.28	4.35	4.42	4.42	4.44	1625
4.46	4.40	4.30	4.22	4.13	4.07	4.12	4.19	4.22	4.23	4.16	4.04	3.99	3.94	3.93	1700
3.91	3.86	3.83	3.80	3.78	3.70	3.54	3.40	3.30	3.31	3.42	3.52	3.52	3.49	3.41	1775
3.21	3.14	3.10	3.06	3.11	2.98	2.88	2.78	2.74	2.76	2.72	2.76	2.82	2.85	2.86	1850
2.75	2.64	2.60	2.61	2.64	2.56	2.49	2.37	2.25	2.14	2.08	2.11	2.20	2.31	2.28	1925
2.15	2.06	1.98	2.03	2.05	1.96	1.84	1.72	1.64	1.59	1.57	1.57	1.60	1.63	1.51	2000
1.38	1.07	0.91	0.87	0.92	1.04	1.01	0.92	0.84	0.92	0.97	1.01	1.06	1.10	1.06	2075
1.01	0.91	0.79	0.55	0.47	0.41	0.39	0.38	0.34	0.33	0.36	0.43	0.48	0.45	0.38	2150
0.27	0.21	0.22	0.29	0.37	0.38	0.37	0.29	0.19	0.13	0.11	0.03	-0.05	-0.12	-0.24	2225
-0.31	-0.39	-0.43	-0.50	-0.59	-0.68	-0.73	-0.80	-0.92	-1.06	-1.14	-1.22	-1.27	-1.28	-1.33	2300
-1.32	-1.43	-1.51	-1.63	-1.74	-1.82	-1.96	-2.09	-2.21	-2.21	-2.24	-2.27	-2.36	-2.31	-2.65	2375
-2.70	-2.63	-2.57	-2.56	-2.59	-2.67	-2.69	-2.67	-2.68	-2.62	-2.52	-2.42	-2.29	-2.14	-2.00	2450
-1.87	-1.71	-1.51	-1.39	-1.27	-1.12	-1.01	-0.89	-0.75	-0.68	-0.57	-0.47	-0.42	-0.32	-0.27	2525
-0.26	-0.19	-0.13	-0.11	-0.01	0.05	0.08	0.17	0.25	0.31	0.41	0.43	0.44	0.43	0.36	2600
0.35	0.31	0.25	0.25	0.22	0.21	0.33	0.49	0.65	0.76	0.71	0.51	0.30	0.13	0.10	2675
0.17	0.24	0.31	0.38	0.45	0.51	0.56	0.60	0.63	0.62	0.63	0.64	0.66	0.69	0.76	2750
0.75	0.74	0.70	0.62	0.53	0.46	0.39	0.38	0.37	0.38	0.42	0.47	0.50	0.58	0.69	2825
0.67	0.62	0.64	0.66	0.76	0.90	1.11	1.13	1.10	0.97	0.98	1.17	1.38	1.52	1.70	2900
1.76	1.84	1.92	1.90	1.87	1.91	2.02	2.13	2.10	2.18	2.22	2.25	2.03	2.01	1.77	2975
1.93	2.19	2.28	2.14	2.15	2.22	2.01	2.14	2.26	2.36	2.51	2.66	2.73	2.68	2.69	3050
2.64	2.22	1.95	1.61	1.11	0.88	0.83	0.89	1.20	1.62	1.82	1.99	2.01	2.14	2.16	3125
2.21	2.30	2.33	2.42	2.50	2.51	2.49	2.46	2.42	2.37	2.37	2.33	2.31	2.43	2.56	3200
2.61	2.63	2.60	2.50	2.38	2.41	2.34	2.31	2.32	2.40	2.27	2.32	2.22	2.09	2.08	3275
2.17	2.41	2.77	2.66	2.49	2.29	2.23	2.42	2.61	2.58	2.49	2.40	2.39	2.51	2.60	3350
2.68	2.68	2.70	2.82	2.83	2.82	2.81	2.84	2.86	2.91	2.96	3.03	3.08	3.21	3.30	3425
3.40	3.52	3.49	3.46	3.51	3.54	3.56	3.55	3.57	3.61	3.71	3.80	3.92	3.99	4.06	3500
4.02	4.06	4.12	4.26	4.30	4.22	4.32	4.42	4.53	4.64	4.55	4.40	4.28	4.32	4.36	3575
4.37	4.24	4.13	4.14	4.20	4.25	4.32	4.35	4.31	4.27	4.25	4.27	4.31	4.36	4.41	3650
4.52	4.59	4.71	4.79	4.81	4.73	4.61	4.42	4.28	4.08	4.00	3.88	3.86	3.92	3.98	3725
4.12	4.18	4.31	4.37	4.42	4.50	4.53	4.58	4.59	4.61	4.61	4.59	4.53	4.49	4.44	3800
4.41	4.40	4.34	4.30	4.26	4.09	3.98	3.87	3.78	3.77	3.79	3.75	3.72	3.62	3.56	3875
3.51	3.48	3.32	3.18	3.07	2.96	2.87	2.80	2.68	2.58	2.59	2.51	2.59	2.57	2.50	3950
2.42	2.32	2.20	2.12	2.00	1.92	1.79	1.63	1.60	1.69	1.78	2.04	2.00	1.81	1.70	4025
1.63	1.61	1.60	1.49	1.14	1.35	1.64	1.69	1.70	1.59	1.45	1.29	1.19	1.08	1.02	4100
1.04	1.10	1.16	1.20	1.23	1.22	1.08	1.08	1.06	0.89	0.93	0.73	0.58	0.54	0.77	4175
0.81	0.74	0.71	0.57	0.49	0.43	0.38	0.12	0.10	0.20	0.41	0.37	0.31	0.11	-0.13	4250
-0.21	-0.32	-0.36	-0.39	-0.33	-0.39	-0.45	-0.50	-0.55	-0.62	-0.68	-0.77	-0.84	-0.91	-1.00	4325
-1.11	-1.19	-1.28	-1.31	-1.39	-1.43	-1.48	-1.52	-1.57	-1.60	-1.61	-1.60	-1.58	-1.51	-1.42	4400
-1.32	-1.26	-1.16	-1.00	-0.83	-0.71	-0.61	-0.52	-0.43	-0.36	-0.30	-0.21	-0.19	-0.17	-0.15	4475
-0.13	-0.17	-0.19	-0.12	-0.06	-0.01	0.00	-0.11	-0.23	-0.32	-0.44	-0.51	-0.48	-0.47	-0.42	4550
-0.40	-0.40	-0.39	-0.37	-0.35	-0.48	-0.75	-1.13	-1.58	-1.80	-1.66	-1.52	-1.35	-1.19	-1.02	4625
-0.88	-0.66	-0.65	-0.63	-0.62	-0.66	-0.73	-0.79	-0.88	-0.84	-0.70	-0.59	-0.43	-0.39	-0.50	4700
-0.61	-0.74	-0.79	-0.76	-0.69	-0.62	-0.59	-0.52	-0.48	-0.48	-0.42	-0.39	-0.38	-0.33	-0.29	4775
-0.26	-0.23	-0.22	-0.28	-0.37	-0.50	-0.60	-0.60	-0.51	-0.46	-0.42	-0.43	-0.45	-0.35	-0.24	4850
-0.14	-0.08	-0.08	0.00	0.11	0.32	0.43	0.42	0.32	0.23	0.22	0.28	0.45	0.55	0.62	4925
0.65	0.71	0.75	0.80	0.83	0.85	0.87	0.90	0.93	1.00	1.04	1.15	1.22	1.32	1.31	5000

Table A2. Listing of Data for LOWTRAN 4 (Cont)

1.32	1.33	1.48	1.78	1.87	2.01	1.92	1.86	1.89	1.92	1.98	2.03	2.39	2.31	2.48	5075
2.70	2.71	2.76	2.78	2.70	2.77	3.08	2.94	3.05	2.94	3.23	3.20	3.19	3.32	3.11	5150
3.41	3.31	3.36	3.46	3.36	3.39	3.50	3.41	3.22	3.19	2.98	2.78	2.98	3.02	2.82	5225
2.98	2.86	2.92	2.92	3.05	3.22	3.60	3.78	3.81	3.96	3.76	3.62	3.34	3.08	3.31	5300
3.16	3.37	3.41	3.30	3.33	3.33	3.51	3.48	3.43	3.52	3.31	3.40	3.58	3.61	3.49	5375
3.46	3.42	3.19	3.18	3.30	3.00	2.99	3.21	3.11	3.14	3.10	2.72	2.81	2.95	2.69	5450
2.73	2.72	2.47	2.51	2.60	2.42	2.37	2.73	1.91	1.87	1.81	1.78	1.53	1.51	1.62	5525
1.59	1.50	1.42	1.32	1.22	1.12	1.08	1.02	0.97	0.92	0.90	0.87	0.84	0.82	0.79	5600
0.78	0.76	0.75	0.72	0.71	0.71	0.70	0.69	0.67	0.61	0.59	0.52	0.48	0.41	0.39	5675
0.38	0.33	0.32	0.30	0.30	0.30	0.29	0.28	0.27	0.26	0.25	0.23	0.22	0.21	0.20	5750
0.18	0.14	0.13	0.06	0.01	-0.03	-0.07	-0.11	-0.16	-0.21	-0.24	-0.29	-0.32	-0.38	-0.41	5825
-0.45	-0.50	-0.54	-0.61	-0.69	-0.76	-0.84	-0.90	-0.97	-1.01	-1.10	-1.13	-1.19	-1.22	-1.28	5900
-1.30	-1.33	-1.36	-1.39	-1.43	-1.48	-1.50	-1.52	-1.57	-1.61	-1.66	-1.70	-1.72	-1.78	-1.81	5975
-1.89	-1.92	-2.00	-2.08	-2.16	-2.24	-2.31	-2.40	-2.48	-2.54	-2.61	-2.71	-2.83	-2.95	-3.10	6050
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6125
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6200
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6275
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6350
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6425
-3.78	-3.33	-3.01	-2.82	-2.68	-2.49	-2.30	-2.13	-2.00	-1.81	-1.60	-1.41	-1.13	-0.90	-0.79	6500
-0.63	-0.48	-0.36	-0.28	-0.16	-0.06	0.08	0.20	0.29	0.41	0.54	0.69	0.80	0.92	1.04	6575
1.19	1.19	1.01	0.98	1.02	1.19	1.29	1.30	1.29	1.33	1.19	1.39	1.42	1.43	1.70	6650
1.62	1.54	1.41	1.53	1.86	1.96	1.97	2.02	2.01	1.94	1.94	1.83	2.03	2.21	2.42	6725
2.30	2.16	2.02	2.02	2.02	2.13	1.90	1.71	2.01	1.56	1.56	1.51	1.30	1.63	1.64	6800
1.67	1.70	2.22	2.32	2.38	2.30	1.93	2.39	2.49	2.52	2.57	2.21	2.18	2.40	2.41	6875
2.45	2.51	2.23	2.49	2.30	2.61	2.72	2.52	2.63	2.56	2.51	2.70	2.62	2.62	2.80	6950
2.74	2.79	2.74	2.70	2.88	2.81	2.72	2.76	2.84	2.92	2.98	2.88	2.88	3.02	3.08	7025
3.26	3.03	3.14	3.28	3.03	3.11	3.15	3.30	3.31	3.22	3.00	3.06	3.34	3.40	3.37	7100
3.32	3.08	3.09	3.09	3.01	3.07	3.07	3.31	3.21	3.31	3.67	3.58	3.79	3.70	3.49	7175
3.39	3.11	3.13	3.01	3.10	3.01	3.18	3.32	3.43	3.35	3.40	3.39	3.39	3.51	3.54	7250
3.42	3.50	3.67	3.59	3.65	3.66	3.48	3.39	3.29	3.31	3.41	3.23	3.32	3.12	2.91	7325
2.91	2.75	2.78	2.72	2.62	2.58	2.32	2.22	2.00	1.97	1.68	1.62	1.64	1.53	1.56	7400
1.51	1.52	1.48	1.42	1.42	1.40	1.41	1.43	1.56	1.52	1.51	1.52	1.39	1.34	1.30	7475
1.09	1.16	1.21	1.20	1.22	1.20	1.18	1.20	1.19	1.17	1.10	1.10	1.09	1.10	1.11	7550
1.04	0.98	0.90	0.86	0.90	0.90	0.90	0.8[illegible]	0.71	0.79	0.70	0.71	0.67	0.62	0.53	7625
0.42	0.31	0.20	0.01	-0.08	-0.17	-0.26	-0.35	-0.44	-0.53	-0.63	-0.73	-0.83	-0.93	-1.04	7700
-1.14	-1.24	-1.34	-1.44	-1.54	-1.64	-1.74	-1.84	-1.94	-2.04	-2.14	-2.24	-2.34	-2.44	-2.54	7775
-2.64	-2.74	-2.84	-2.94	-3.04	-3.14	-3.24	-3.34	-3.44	-3.54	-3.64	-3.74	-3.84	-3.94	-4.04	7850
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	7925
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	8000
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	8075
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	8150
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	8225
-4.15	-4.06	-3.97	-3.88	-3.79	-3.70	-3.61	-3.52	-3.43	-3.34	-3.25	-3.16	-3.07	-2.98	-2.89	8300
-2.80	-2.71	-2.62	-2.53	-2.44	-2.35	-2.26	-2.18	-2.09	-2.00	-1.91	-1.82	-1.73	-1.64	-1.55	8375
-1.46	-1.37	-1.28	-1.19	-1.10	-1.01	-0.92	-0.83	-0.74	-0.65	-0.56	-0.47	-0.38	-0.29	-0.20	8450
-0.14	-0.09	-0.02	0.03	0.10	0.17	0.22	0.30	0.35	0.41	0.45	0.42	0.40	0.43	0.46	8525
0.50	0.59	0.71	0.84	0.93	1.01	1.06	1.07	1.02	1.01	1.12	1.23	1.24	1.28	1.34	8600
1.43	1.52	1.56	1.59	1.56	1.51	1.61	1.50	1.70	1.82	1.92	1.94	1.89	1.81	1.45	8675
1.30	1.28	1.43	1.50	1.49	1.55	1.48	1.32	1.39	1.53	1.82	2.23	2.61	2.51	2.20	8750

SPECTRAL DATA H_2O

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 1.86 1.61 1.19 1.32 1.52 1.70 1.90 2.01 1.92 1.91 2.12 2.10 2.01 2.18 1.99 8875
 2.11 2.28 2.21 2.13 2.00 1.91 1.92 1.97 1.88 1.91 1.91 1.92 1.93 1.74 1.61 8900
 1.58 1.27 1.20 1.18 1.11 0.99 0.86 0.71 0.60 0.44 0.31 0.19 0.03-0.07-0.21 8975
-0.35-0.49-0.64-0.79-0.94-1.11-1.24-1.41-1.57-1.73-1.91-2.09-2.27-2.45-2.63 9050
-2.81-2.99-3.18-3.37-3.56-3.75-3.94-4.13-4.31-4.49-4.66-4.83-4.99-5.14-5.28 9125
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.68-4.26-3.89-3.57-3.32-3.11-2.91 9875
-2.89-2.79-2.74-2.63-2.47-2.29-2.20-2.17-2.23-2.27-2.32-2.12-2.08-2.07-2.07 9950
-2.07-1.98-1.77-1.70-1.63-1.60-1.59-1.43-1.21-1.15-1.09-1.13-1.29-1.19-0.9810025
-0.93-0.87-0.91-0.88-0.71-0.62-0.59-0.58-0.63-0.58-0.39-0.22-0.14-0.06-0.0110100
-0.01-0.08-0.20-0.16-0.02 0.18 0.32 0.42 0.37 0.23 0.12 0.15 0.28 0.43 0.5910175
 0.58 0.53 0.44 0.39 0.38 0.35 0.23 0.26 0.19 0.08 0.10 0.18 0.27 0.38 0.4310250
 0.32 0.37 0.58 0.64 0.87 0.98 1.00 1.02 1.13 1.08 1.08 1.16 1.16 1.30 1.4110325
 1.40 1.32 1.22 1.37 1.42 1.50 1.42 1.38 1.36 1.38 1.49 1.63 1.62 1.62 1.7010400
 1.68 1.60 1.56 1.56 1.63 1.64 1.56 1.49 1.49 1.52 1.58 1.62 1.62 1.61 1.6110475
 1.62 1.63 1.71 1.72 1.70 1.70 1.67 1.62 1.66 1.70 1.67 1.56 1.49 1.42 1.3810550
 1.26 1.20 1.13 1.14 1.19 1.29 1.50 1.72 1.85 1.78 1.82 1.88 1.87 1.89 1.9910625
 2.00 2.14 2.04 2.02 2.02 1.98 1.90 1.83 1.81 1.72 1.69 1.59 1.50 1.36 1.2010700
 0.98 0.63 0.43 0.29 0.16 0.05 0.02 0.03 0.03 0.01-0.08-0.18-0.20-0.11-0.0610775
-0.03-0.14-0.21-0.08-0.06 0.10 0.18 0.11 0.32 0.42 0.44 0.38 0.20 0.42 0.4310850
 0.41 0.33 0.32 0.41 0.50 0.46 0.31 0.18 0.03 0.20 0.21 0.34 0.36 0.26 0.3510925
 0.39 0.42 0.38 0.32 0.30 0.16-0.01-0.23-0.41-0.52-0.48-0.58-0.61-0.48-0.2311000
-0.03 0.21 0.36 0.39 0.47 0.44 0.40 0.51 0.59 0.53 0.69 0.57 0.48 0.52 0.6211075
 0.59 0.55 0.50 0.32 0.26 0.11-0.08-0.10-0.16-0.43-0.62-0.88-1.09-1.16-1.3111150
-1.45-1.49-1.78-1.91-2.01-1.97-1.97-1.97-1.97-2.20-2.20-2.01-1.99-2.00-2.0411225
-2.37-2.49-2.44-2.36-2.32-2.19-2.10-2.25-2.16-2.36-2.44-2.40-2.49-2.48-2.4311300
-2.40-2.36-2.40-2.49-2.59-2.68-2.89-3.28-3.51-3.74-3.97-4.20-4.43-4.66-4.8911375
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0011450
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0011525
-5.00-5.00-5.0 -5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0011600
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0011675
-3.71-3.56-3.40-3.21-3.06-2.90-2.74-2.60-2.46-2.32-2.17-2.03-1.87-1.79-1.7411750
-1.83-1.82-1.71-1.59-1.49-1.46-1.46-1.49-1.49-1.25-1.24-1.08-0.90-1.06-0.9111825
-0.91-1.01-0.99-0.87-0.92-0.79-0.42-0.54-0.38-0.42-0.48-0.34-0.27-0.17-0.2811900
-0.38-0.22-0.30-0.08-0.01-0.20 0.06 0.10 0.06 0.14-0.12-0.02-0.02-0.13-0.1111975
-0.10-0.06-0.05-0.04-0.10-0.04-0.06-0.21-0.38-0.61-0.40-0.31-0.42-0.58-0.5712050
-0.54-0.24 0.11 0.51 0.81 0.79 0.62 0.26-0.31-0.67-0.80-0.88-0.50-0.39-0.1012125
 0.09 0.06 0.08 0.16 0.21 0.13 0.32 0.35 0.51 0.60 0.51 0.51 0.40 0.40 0.4312200
 0.42 0.33 0.43 0.34 0.22 0.13-0.11-0.31-0.31-0.41-0.41-0.39-0.53-0.69-0.8412275
-0.88-1.01-1.10-1.19-1.29-1.45-1.49-1.67-1.67-1.51-1.66-1.60-1.69-1.63-1.5112350
-1.42-1.40-1.24-1.38-1.31-1.30-1.30-1.28-1.39-1.33-1.40-1.35-1.37-1.39-1.4112425
-1.49-1.48-1.56-1.47-1.46-1.41-1.42-1.48-1.41-1.31-1.15-1.13-1.20-1.41-1.8812500
-2.08-2.08-2.22-2.35-2.35-1.98-1.92-1.78-1.57-1.69-1.70-1.70-1.66-1.84-1.5012575
-1.56-1.42-1.29-1.38-1.28-1.48-1.58-1.44-1.53-1.48-1.48-1.50-1.58-1.69-1.7912650
-2.00-2.16-1.99-2.23-2.04-2.04-2.39-2.74-3.09-3.44-3.79-4.14-4.49-4.84-5.1912725
-2.46-2.26-1.99-2.01-2.14-2.31-2.15-2.01-1.99-2.14-2.41-2.12-1.99-1.84-1.7913400
-1.71-1.78-1.72-1.68-1.78-1.52-1.38-1.29-1.22-0.91-0.90-1.01-0.76-0.90-0.9013475
-0.96-1.19-1.00-0.79-0.68-0.68-0.73-0.85-0.85-0.61-0.61-0.48-0.51-0.92-0.8313550
-0.61-0.41-0.29-0.29-0.61-0.74-0.19-0.18 0.    0.19-0.10 0.20 0.20 0.02  .2013625
-0.01 0.18 0.28 0.11 0.   -0.37-0.10 0.02 0.16 0.20 0.    0.09 0.09 0.09 0.0713700
 0.22 0.11 0.11 0.21 0.09 0.21 0.20 0.37 0.28 0.07 0.09-0.29-0.69-0.69-0.7413775
```

SPECTRAL DATA H_2O

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
-0.88-1.01-0.86-0.54-0.19 0.19 0.23 0.21 0.29 0.28 0.29 0.52 0.54 0.51  .6013850
 0.40 0.49 0.48 0.46 0.49 0.27 0.06-0.33-0.81-1.17-1.11-1.37-1.52-1.54-1.9413925
-2.06-2.06-2.14-1.96-2.00-2.00-2.08-2.23-2.31-2.31-2.53-2.31-2.31-2.31-2.2814000
-2.34-2.34-1.91-1.82-1.69-1.56-1.84-1.91-1.75-1.83-1.76-1.54-1.98-1.80-1.6814075
-1.69-1.56-1.60-1.71-1.36-1.36-1.44-1.48-1.40-1.48-1.36-1.45-1.49-1.85-1.3914150
-1.23-1.18-1.18-1.34-1.36-1.23-1.23-1.37-1.30-1.40-1.28-1.27-1.37-1.32-1.3214225
-1.22-1.28-1.38-1.69-2.07-2.42-2.58-2.58-2.89-2.58-2.43-1.88-1.60-1.26-1.1614300
-1.23-1.10-1.23-1.10-0.83-0.80-0.80-0.80-0.98-0.97-0.97-0.91-0.92-1.13-1.2414375
-1.50-1.89-2.18-2.32-2.63-3.91-4.20-4.49-4.78-5.07-5.07-5.07-5.07-5.07-5.0714450
-4.25-3.70-3.20-2.75-1.90-1.73-1.51-1.29-1.11-0.91-0.71-0.51-0.30-0.06 0.22   500
 0.49 0.76 1.08 1.29 1.56 1.76 1.91 2.08 2.23 2.36 2.51 2.72 2.90 3.12 3.37   575
 3.56 3.69 3.79 3.86 3.88 3.86 3.73 3.58 3.39 3.17 2.86 2.73 2.52 2.31 2.17   650
 2.01 1.89 1.77 1.63 1.47 1.21 0.92 0.53 0.23-0.17-0.53-0.74-0.81-0.84-0.88   725
-1.00-1.18-1.42-1.61-1.86-2.10-2.29-2.51-2.72-2.91-3.14-5.00-5.00-5.00-5.00   800
-5.00-5.00-5.00-5.00-5.00-5.00-2.68-2.47-2.19-1.97-1.71-1.50-1.32-1.21-1.13   875
-1.09-1.11-1.10-1.09-1.01-1.01-1.11-1.33-1.66-2.13-2.51-2.83-2.71-2.39-2.09   950
-1.78-1.59-1.33-1.18-1.01-0.96-0.91-0.90-0.87-0.80-0.79-0.86-1.07-1.28-1.69  1025
-2.11-2.74-3.09-3.50-3.03-2.58-2.23-1.89-1.54-1.28-1.13-1.11-1.16-1.20-1.23  1100
-1.21-1.17-1.12-1.15-1.19-1.20-1.17-1.02-0.89-0.68-0.42-0.24-0.01 0.18 0.40  1175
 0.57 0.77 0.96 1.07 1.13 1.11 1.08 1.15 1.27 1.33 1.44 1.40 1.13 0.89 0.63  1250
 0.54 0.65 0.78 0.81 0.86 0.82 0.68 0.47 0.14-0.12-0.48-0.92-1.43-1.99-2.72  1325
-2.81-5.00-5.00-5.00-3.14-2.47-2.00-1.71-1.59-1.61-1.69-1.82-1.87-1.90-1.94  1400
-2.04-2.10-2.23-2.32-2.48-2.71-2.88-3.09-2.99-2.43-2.00-1.69-1.42-1.38-1.49  1475
-1.70-2.01-2.41-2.64-2.63-2.49-2.38-2.27-2.16-2.05-1.94-1.83-1.76-1.71-1.70  1550
-1.72-1.81-1.92-2.03-2.27-2.61-3.21-4.01-5.00-5.00-5.00-5.00-5.00-5.00-5.00  1625
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00  1700
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.30-3.42-3.17-2.98  1775
-2.83-2.71-2.67-2.67-2.68-2.58-2.33-2.01-1.64-1.32-0.97-0.76-0.63-0.59-0.60  1850
-0.63-0.69-0.87-1.08-1.26-1.53-1.87-1.91-1.93-2.02-2.21-2.48-2.80-3.08-3.11  1925
-3.09-2.93-2.76-2.39-2.01-1.69-1.36-0.99-0.63-0.28 0.00 0.08 0.11 0.12 0.12  2000
 0.07 0.01-0.08-0.23-0.40-0.51-0.53-0.57-0.60-0.61-0.73-0.81-0.95-1.05-1.02  2075
-0.91-0.68-0.41-0.09 0.16 0.41 0.76 1.00 1.16 1.39 1.51 1.58 1.68 1.71 1.80  2150
 1.91 2.02 2.18 2.32 2.50 2.61 2.69 2.81 2.89 2.96 3.04 3.14 3.27 3.41 3.55  2225
 3.72 3.90 4.03 4.22 4.42 4.61 4.71 4.73 4.65 4.63 4.72 4.78 4.79 4.50 3.62  2300
 3.23 2.79 2.30 1.86 1.35 0.52-0.24-1.69-2.18-2.01-1.79-1.53-1.32-1.20-1.15  2375
-1.12-1.18-1.25-1.26-1.20-1.17-1.20-1.32-1.54-1.84-2.16-2.30-2.26-2.01-1.71  2450
-1.36-1.06-0.81-0.61-0.49-0.45-0.47-0.49-0.46-0.37-0.31-0.34-0.49-0.75-1.11  2525
-1.43-2.01-2.60-2.89-2.87-2.74-2.51-2.42-2.38-2.39-2.42-2.46-2.48-2.49-2.43  2600
-2.43-2.46-2.53-2.68-2.74-2.82-2.87-2.83-2.82-2.79-2.71-2.66-2.49-2.40-2.32  2675
-2.26-2.23-2.20-2.09-2.02-1.96-1.88-1.84-1.85-1.86-1.87-1.83-1.79-1.73-1.68  2750
-1.64-1.69-1.74-1.79-1.87-1.78-1.63-1.50-1.37-1.21-1.00-0.83-0.69-0.55-0.41  2825
-0.30-0.19-0.09-0.04 0.02 0.10 0.16 0.18 0.23 0.26 0.27 0.26 0.24 0.22 0.17  2900
 0.12 0.07-0.01-0.07-0.09 0.32 0.72 0.91 1.12 1.03 0.67 0.18-0.11-0.38-0.29  2975
-0.17-0.08-0.00 0.09 0.13 0.18 0.24 0.27 0.29 0.30 0.29 0.26 0.23 0.21 0.13  3050
 0.09 0.02-0.04-0.18-0.32-0.51-0.72-0.99-1.18-1.50-1.62-1.81-2.04-2.29-2.49  3125
-2.62-2.87-3.03-3.21-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00  3200
-5.00-4.01-3.38-3.01-2.63-2.32-2.09-1.98-1.94-2.00-2.14-2.26-2.20-2.02-1.82  3275
-1.59-1.43-1.38-1.46-1.64-1.90-2.09-2.54-2.91-3.28-3.61-3.72-3.64-3.50-3.41  3350
-3.37-3.30-3.16-3.01-2.76-2.51-2.20-1.80-1.49-1.22-0.97-0.72-0.49-0.20 0.03  3425
 0.20 0.36 0.51 0.61 0.67 0.83 1.00 1.22 1.39 1.56 1.70 1.86 2.01 2.20 2.31  3500
```

SPECTRAL DATA UNIFORMLY MIXED GASES

Table A2. Listing of Data for LOWTRAN 4 (Cont)

2.47	2.61	2.76	2.92	3.01	3.05	3.02	2.98	2.98	3.01	3.03	2.97	2.78	2.44	2.13	3575
1.83	1.79	1.49	1.50	1.67	1.94	2.22	2.50	2.71	2.93	3.12	3.18	3.17	3.15	3.21	3650
3.26	3.19	2.98	2.59	2.14	1.70	1.22	0.55	-0.27	-1.09	-2.54	-3.06	-2.94	-2.78	-2.68	3725
-2.61	-2.60	-2.63	-2.60	-2.57	-2.53	-2.57	-2.64	-2.77	-3.04	-3.38	-3.98	-5.00	-5.00	-5.00	3800
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	3875
-5.00	-4.00	-3.73	-3.62	-3.59	-3.53	-3.56	-3.57	-3.53	-3.51	-3.45	-3.37	-3.26	-3.21	-3.18	3950
-3.27	-3.36	-3.60	-3.96	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	4025
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-4.62	4100
-4.07	-3.89	-3.76	-3.67	-3.56	-3.42	-3.35	-3.26	-3.18	-3.14	-3.11	-3.09	-3.10	-3.12	-3.23	4175
-3.30	-3.38	-3.37	-3.29	-3.14	-3.08	-3.00	-2.93	-2.89	-2.91	-3.00	-3.08	-3.16	-3.31	-3.48	4250
-3.71	-3.98	-5.00	-5.00	-5.00	-5.00	-4.52	-3.98	-3.69	-3.42	-3.18	-2.95	-2.77	-2.61	-2.48	4325
-2.41	-2.41	-2.40	-2.38	-2.34	-2.27	-2.21	-2.31	-2.49	-2.73	-3.21	-4.13	-5.00	-5.00	-5.00	4400
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	4475
-5.00	-5.00	-4.13	-4.02	-3.99	-3.96	-3.87	-3.73	-3.51	-3.29	-3.13	-2.99	-2.84	-2.73	-2.69	4550
-2.68	-2.69	-2.65	-2.62	-2.59	-2.57	-2.62	-2.61	-3.04	-3.21	-3.39	-3.42	-3.36	-3.21	-3.03	4625
-2.93	-2.80	-2.64	-2.52	-2.37	-2.28	-2.20	-2.13	-2.07	-2.02	-1.96	-1.86	-1.78	-1.63	-1.44	4700
-1.31	-1.20	-1.08	-0.98	-0.94	-0.86	-0.76	-0.52	-0.31	-0.03	0.13	0.30	0.37	0.36	0.36	4775
0.35	0.35	0.39	0.46	0.48	0.41	0.23	-0.08	-0.38	-0.67	-0.88	-0.96	-0.98	-0.87	-0.67	4850
-0.36	-0.12	0.14	0.44	0.68	0.90	1.11	1.19	1.24	1.25	1.26	1.27	1.51	1.59	1.50	4925
1.28	0.71	0.11	-0.28	-0.67	-1.32	-1.61	-1.58	-1.42	-1.18	-0.91	-0.59	-0.27	-0.06	0.29	5000
0.57	0.73	0.92	0.91	0.73	0.79	0.91	1.01	1.03	0.88	0.72	0.63	0.38	0.12	-0.21	5075
-0.47	-0.67	-1.23	-1.67	-2.31	-2.76	-3.24	-3.49	-3.51	-3.47	-3.39	-3.37	-3.43	-3.53	-3.50	5150
-3.36	-3.18	-3.07	-2.96	-3.08	-3.14	-3.12	-3.23	-3.07	-2.83	-2.47	-2.23	-2.07	-1.91	-1.78	5225
-1.63	-1.46	-1.27	-1.23	-1.26	-1.40	-1.57	-1.98	-2.28	-2.87	-3.74	-5.00	-5.00	-5.00	-5.00	5300
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5375
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5450
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5525
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5600
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5675
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5750
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	5825
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-4.91	-4.79	-4.61	5900
-4.48	-4.40	-4.29	-4.17	-3.90	-3.73	-3.59	-3.62	-3.72	-3.73	-3.69	-3.31	-3.12	-2.91	-2.63	5975
-2.41	-2.27	-2.16	-2.11	-2.28	-2.29	-2.21	-2.06	-1.91	-1.99	-2.27	-2.59	-2.96	-3.35	-3.69	6050
-3.79	-3.68	-3.53	-3.46	-3.39	-3.31	-3.18	-2.97	-2.69	-2.39	-2.11	-1.83	-1.58	-1.49	-1.22	6125
-1.08	-0.89	-0.68	-0.54	-0.71	-0.79	-0.78	-0.66	-0.43	-0.54	-0.86	-1.37	-2.08	-2.44	-3.46	6200
-3.72	-3.74	-3.59	-3.22	-2.98	-2.52	-2.21	-1.64	-1.34	-1.08	-0.86	-0.72	-0.61	-0.70	-0.72	6275
-0.67	-0.57	-0.38	-0.51	-0.97	-1.36	-1.89	-2.74	-3.18	-4.21	-4.57	-4.62	-4.76	-4.87	-5.00	6350
-5.00	-5.00	-5.00	-5.00	-5.00	-4.93	-4.46	-3.99	-3.45	-2.99	-2.63	-2.30	-2.09	-2.02	-2.12	6425
-2.18	-2.13	-2.04	-1.78	-1.83	-2.08	-2.28	-2.61	-3.01	-3.15	-3.22	-3.29	-3.58	-3.89	-4.46	6500
-4.88	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	6575
-4.81	-4.52	-4.11	-3.69	-3.09	-2.99	-2.91	-2.89	-3.19	-3.20	-3.36	-3.62	-3.89	-3.92	-3.73	6650
-3.53	-3.37	-3.19	-3.02	-2.79	-2.52	-2.36	-2.24	-2.19	-2.32	-2.41	-2.29	-2.06	-2.00	-2.18	6725
-2.47	-2.91	-3.57	-4.89	-5.00	-5.00	-5.00	-5.00	-5.00	-4.61	-4.18	-3.89	-3.57	-3.30	-3.02	6800
-2.74	-2.51	-2.20	-1.96	-1.73	-1.57	-1.38	-1.21	-1.11	-0.98	-0.87	-0.78	-0.60	-0.37	-0.18	6875
-0.04	-0.04	-0.06	-0.16	-0.18	-0.19	-0.23	-0.45	-1.02	-1.97	-2.70	-3.71	-4.01	-4.20	-4.35	6950
-4.58	-4.73	-4.81	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	7025
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	7100
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	71 5
-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00	7250

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 7325
-5.00-5.00-5.00-4.71-4.31-3.99-3.68-3.50-3.34-3.22-3.23-3.25-3.24-3.18-3.10 7400
-3.07-3.18-3.41-3.67-4.12-4.68-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.51-4.16 7475
-3.73-3.48-3.17-2.96-2.73-2.63-2.58-2.59-2.57-2.49-2.42-2.38-2.48-2.62-3.02 7550
-3.49-4.16-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.87-4.90 7625
-4.21-3.90-3.66-3.56-3.51-3.51-3.51-3.49-3.41-3.34-3.34-3.47-3.60-3.87-4.23 7700
-4.59-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.93 7775
-4.51-4.10-3.78-3.32-3.03-2.74-2.43-2.08-1.83-1.59-1.29-1.02-0.81-0.70-0.73 7850
-0.90-1.08-1.19-1.35-1.47-1.57-1.66-1.80-1.91-2.04-2.18-2.33-2.47-2.61-2.78 7925
-2.97-3.10-3.28-3.44-3.63-3.81-3.98-4.15-4.32-4.61-4.71-4.80-5.00-5.00-5.00 8000
-5.00-5.00-5.00-5.00-4.32-3.24-2.59-2.12-1.82-1.57-1.34-1.15-1.02-0.82-0.6412950
-0.48-0.33-0.14-0.06 0.08 0.21 0.39 0.52 0.61 0.72 0.85 0.96 1.02 1.12 1.1813025
 1.21 1.17 1.08 0.96 0.90 0.97 1.13 1.27 1.58 1.74 1.70 1.48 1.13 0.73 0.2213100
-0.51-1.57-3.46-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.0013175
-4.15-3.51-3.00-2.54-2.12-1.76-1.50-1.21-0.86-0.49-0.29-0.10 0.02 0.12 0.24  575
 0.32 0.43 0.52 0.58 0.65 0.72 0.79 0.76 0.72 0.68 0.64 0.68 0.79 0.83 0.83  650
 0.80 0.78 0.68 0.56 0.49 0.42 0.34 0.26 0.14 0.02-0.14-0.39-0.51-0.74-0.88  725
-1.17-1.40-1.58-2.11-2.47-2.83-3.26-3.59-3.94-5.00-5.00-5.00-5.00-5.00-5.0   800
-5.00-5.00-5.00-5.00-5.00-4.46-4.00-3.50-3.14-2.78-2.41-2.10-1.78-1.49-1.20  875
-0.70 0.15 0.35 0.57 0.78 0.95 1.20 1.40 1.65 1.80 1.97 2.10 2.21 2.31 2.38  950
 2.50 2.42 2.58 2.52 2.20 2.48 2.54 2.45 2.30 2.00 1.20 0.95 0.92 0.90 0.90 1025
 0.89 0.90 0.92 0.94 0.95 0.96 0.95 0.90 0.80 0.68 0.55 0.46 0.30 0.19 0.08 1100
-0.02-0.11-0.22-0.41-0.56-0.71-0.89-1.03-1.18-1.33-1.60-1.76-1.90-2.02-2.21 1175
-2.46-2.59-2.79-3.00-3.22-3.61-4.16-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1250
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1325
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1400
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 1475
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.16-3.91-3.66-3.41-3.05-2.69 1550
-2.44-2.19-2.03-1.86-1.71-1.56-1.48-1.39-1.26-1.13-0.97-0.81-0.65-0.48-0.35 1625
-0.22-0.14-0.06-0.02-0.09-0.18-0.14 0.06 0.26-0.02-0.42-0.80-0.82-0.80-0.74 1700
-0.74-0.79-0.84-0.89-0.85-0.81-0.76-0.70-0.68-0.64-0.65-0.66-0.72-0.78-0.84 1775
-0.90-1.02-1.14-1.24-1.33-1.47-1.61-1.77-1.92-1.99-2.04-2.08-2.09-2.06-2.03 1850
-1.98-1.93-1.87-1.82-1.76-1.71-1.65-1.59-1.51-1.44-1.36-1.28-1.18-1.08-0.98 1925
-0.88-0.78-0.69-0.59-0.49-0.37-0.25-0.18-0.10 0.00 0.16 0.27 0.38 0.57 0.75 2000
 0.93 1.11 1.20 1.33 1.44 1.46 1.48 1.48 1.64 1.58 1.49 1.23 0.66 0.38-0.33 2075
-0.71-0.66-0.58-0.49-0.44-0.40-0.40-0.46-0.53-0.64-0.76-0.89-1.01-1.14-1.26 2150
-1.40-1.55-1.69-1.83-1.98-2.13-2.28-2.43-2.64-2.86-3.07-3.28-3.50-3.72-3.94 2225
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2300
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2375
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2450
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00 2525
-5.00-5.00-5.00-5.00-5.00-5.00-5.00-5.00-4.16-3.97-3.77-3.58-3.38-3.07-2.75 2600
-2.44-2.12-1.85-1.57-1.30-1.07-0.98-0.94-0.89-0.85-0.81-0.77-0.72-0.68-0.63 2675
-0.58-0.53-0.48-0.41-0.34-0.26-0.19-0.17-0.18-0.19-0.46-0.79-1.12-1.45-1.75 2750
-2.38-2.97-3.57-4.16-5.00-5.00-5.00-4.16-3.90-3.63-3.37-3.10-2.79-2.47-2.15 2825
-1.84-1.73-1.63-1.52-1.41-1.33-1.25-1.17-1.09-1.02-0.96-0.89-0.82-0.73-0.68 2900
-0.54-0.42-0.27-0.12 0.03 0.18 0.25 0.31 0.39 0.47 0.48 0.49 0.50 0.50 0.48 2975
 0.46 0.23 0.01-0.11-0.33-0.55-0.77-0.83-0.88-0.94-0.92-0.91-0.90-0.85-0.80 3050
-0.76-0.71-0.69-0.67-0.66-0.65-0.65-0.66-0.67-0.68-0.70-0.72-0.82-0.93-1.03 3125
-1.14-1.24-1.34-1.51-1.68-2.13-2.57-2.92-3.26-3.71-4.16-5.00-5.00-5.00-5.00 3200
```

SPECTRAL DATA - ZONE

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
2.93E-04 3.86E-04 5.09E-04 6.56E-04 8.85E-04 1.06E-03 1.31E-03 1.73E-03      2080
2.27E-03 2.73E-03 3.36E-03 3.95E-03 5.46E-03 7.19E-03 9.00E-03 1.13E-02      2120
1.36E-02 1.66E-02 1.96E-02 2.16E-02 2.36E-02 2.63E-02 2.90E-02 3.15E-02      2160
3.40E-02 3.66E-02 3.92E-02 4.26E-02 4.60E-02 4.95E-02 5.30E-02 5.65E-02      2200
6.00E-02 6.30E-02 6.60E-02 6.89E-02 7.18E-02 7.39E-02 7.60E-02 7.84E-02      2240
8.08E-02 8.39E-02 8.70E-02 9.13E-02 9.56E-02 1.08E-01 1.20E-01 1.36E-01      2280
1.52E-01 1.60E-01 1.69E-01 1.60E-01 1.51E-01 1.37E-01 1.23E-01 1.19E-01      2320
1.16E-01 1.14E-01 1.12E-01 1.12E-01 1.11E-01 1.11E-01 1.12E-01 1.14E-01      2360
1.13E-01 1.12E-01 1.09E-01 1.07E-01 1.02E-01 9.90E-02 9.50E-02 9.00E-02      2400
8.65E-02 8.20E-02 7.65E-02 7.05E-02 6.50E-02 6.10E-02 5.50E-02 4.95E-02      2440   N2 CONTINUUM
4.50E-02 4.00E-02 3.75E-02 3.50E-02 3.10E-02 2.65E-02 2.50E-02 2.20E-02      2480
1.95E-02 1.75E-02 1.60E-02 1.40E-02 1.20E-02 1.05E-02 9.50E-03 9.00E-03      2520
8.00E-03 7.00E-03 6.50E-03 6.00E-03 5.50E-03 4.75E-03 4.00E-03 3.75E-03      2560
3.50E-03 3.00E-03 2.50E-03 2.25E-03 2.00E-03 1.85E-03 1.70E-03 1.60E-03      2600
1.50E-03 1.50E-03 1.54E-03 1.50E-03 1.47E-03 1.34E-03 1.25E-03 1.06E-03      2640
9.06E-04 7.53E-04 6.41E-04 5.09E-04 4.04E-04 3.36E-04 2.86E-04 2.32E-04      2680
1.94E-04 1.57E-04 1.31E-04 1.02E-04 8.07E-05                                 2720
0.00 .187 .147 .117 .097 .087 .10  .120 .147 .174 .20  .24  .28  .33  .40    2350   H2O
4.50E-03 8.00E-03 1.07E-02 1.10E-02 1.27E-02 1.71E-02 2.00E-02 2.45E-02     13000
3.07E-02 3.84E-02 4.78E-02 5.67E-02 6.54E-02 7.62E-02 9.15E-02 1.00E-01     14600
1.09E-01 1.20E-01 1.26E-01 1.12E-01 1.11E-01 1.16E-01 1.19E-01 1.13E-01     16200
1.03E-01 9.24E-02 8.28E-02 7.57E-02 7.07E-02 6.58E-02 5.66E-02 4.77E-02     17800
4.06E-02 3.87E-02 3.82E-02 2.94E-02 2.09E-02 1.80E-02 1.91E-02 1.66E-02     19400   OZONE UV & VISIBLE
1.17E-02 7.70E-03 6.10E-03 8.50E-03 6.10E-03 3.70E-03 3.20E-03 3.10E-03     21000
2.55E-03 1.98E-03 1.40E-03 8.25E-04 2.50E-04 0.00E-04 0.00E-04 0.00E-04     22600
5.65E-04 2.04E-03 7.35E-03 2.03E-02 4.98E-02 1.18E-01 2.46E-01 5.18E-01     27800
1.02E+00 1.95E+00 3.79E+00 6.65E+00 1.24E+01 2.20E+01 3.67E+01 5.95E+01     31500
8.50E+01 1.26E+02 1.66E+02 2.06E+02 2.42E+02 2.71E+02 2.91E+02 3.02E+02     35500
3.03E+02 2.94E+02 2.77E+02 2.54E+02 2.26E+02 1.96E+02 1.68E+02 1.44E+02     39500
1.17E+02 9.75E+01 7.65E+01 6.04E+01 4.62E+01 3.46E+01 2.62E+01 2.00E+01     43500
1.57E+01 1.20E+01 1.00E+01 3.80E+00 8.30E+00 8.60E+00                       47500
 5  1  2
    2.500      8.500     65.000
 2350.000  2450.000      5.000                                                      SAMPLE OF INPUT DATA
 2
 6  7  1  0  1
 .200 .20832 .02054  .250 .19518 .00864  .300 .18479 .00442  .400 .17032 .00243
 .488 .16213 .00193  .550 .15800 .00186  .694 .15001 .00155  .860 .14412 .00171
1.060 .13909 .00191 1.536 .12754 .00191 1.800 .12049 .00145 2.000 .11530 .00218   MARITIME MODEL
2.500 .09962 .00336 3.000 .10426 .05258 3.500 .09899 .00658 3.750 .09191 .00271
4.000 .08670 .00314 5.000 .07012 .00578 5.500 .05928 .00507 6.000 .05485 .02351
7.200 .04758 .00942 7.900 .04063 .00923 8.200 .03960 .01006 8.500 .04045 .01125
8.700 .04267 .01114 9.000 .04208 .01119 9.200 .03962 .01141 9.500 .03552 .01011
 9.80 .03257 .00983 10.00 .03051 .00987 10.59 .02582 .01089 11.00 .02470 .01330
11.50 .02556 .01663 12.50 .03085 .02354 13.00 .03339 .02575 14.00 .03688 .02827
15.00 .03888 .02948 16.40 .04021 .02964 17.20 .04121 .02936 18.50 .03951 .02769
20.00 .03648 .02537 22.50 .03232 .02263 25.00 .02901 .02053 30.00 .02420 .01775
 0.        0.        0.        10.
 1820.     20000.    5.
 2
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 6  7  1  0  1
 .200 .31030 .10692  .250 .28416 .08649  .300 .25805 .07571  .400 .20867 .06376
 .488 .17631 .05674  .550 .15800 .05282  .694 .12601 .04528  .860 .10071 .04022
1.060 .08140 .03564 1.536 .05408 .02769 1.800 .04465 .02408 2.000 .03899 .02115
2.500 .03211 .01827 3.000 .02838 .01699 3.500 .02545 .01360 3.750 .02421 .01274
4.000 .02319 .01223 5.000 .02010 .01078 5.500 .01896 .01045 6.000 .01776 .01023
7.200 .01747 .01072 7.900 .01445 .00953 8.200 .01384 .01037 8.500 .01757 .01251
8.700 .01854 .01172 9.000 .01900 .01262 9.200 .01939 .01278 9.500 .01748 .01075
 9.80 .01669 .00973 10.00 .01644 .00954 10.59 .01555 .00868 11.00 .01499 .00796
11.50 .01452 .00765 12.50 .01373 .00727 13.00 .01347 .00721 14.00 .01294 .00707
15.00 .01315 .00843 16.40 .01297 .00751 17.20 .01333 .00776 18.50 .01245 .00712
20.00 .01262 .00741 22.50 .01209 .00719 25.00 .01143 .00691 30.00 .01050 .00668
 0.        0.        0.        10.
 1820.     20000.    5.
 2
 6  7  1  0  1
 .200 .38223 .07945  .250 .32979 .03661  .300 .28540 .02110  .400 .22025 .01317
 .488 .17989 .01114  .550 .15807 .01095  .694 .12064 .00968  .860 .09151 .01058
1.060 .07078 .01070 1.536 .04184 .00933 1.800 .03126 .00736 2.000 .02510 .00437
2.500 .02068 .00463 3.000 .01900 .00584 3.500 .01767 .00250 3.750 .01699 .00214
4.000 .01654 .00232 5.000 .01533 .00321 5.500 .01479 .00388 6.000 .01389 .00462
7.200 .01569 .00745 7.900 .01102 .00617 8.200 .01019 .00807 8.500 .01778 .01254
8.700 .01994 .01126 9.000 .02112 .01209 9.200 .02213 .01376 9.500 .01870 .01005
 9.80 .01744 .00832 10.00 .01714 .00810 10.59 .01588 .00680 11.00 .01514 .00570
11.50 .01455 .00535 12.50 .01365 .00516 13.00 .01339 .00523 14.00 .01286 .00538
15.00 .01368 .00834 16.40 .01384 .00696 17.20 .01480 .00767 18.50 .01353 .00677
20.00 .01427 .00767 22.50 .01381 .00767 25.00 .01302 .00749 30.00 .01204 .00761
 0.        0.        0.        10.
 1820.     20000.    5.
 2
 6  7  1  0  1
 .200 .40212 .08042  .250 .34505 .03451  .300 .29674 .01767  .400 .22565 .00971
 .488 .18187 .00772  .550 .15809 .00745  .694 .11722 .00619  .860 .08537 .00683
1.060 .06265 .00685 1.536 .03078 .00549 1.800 .01912 .00348 2.000 .01241 .00173
2.500 .00783 .00183 3.000 .00629 .00251 3.500 .00420 .00076 3.750 .00354 .00063
7.200 .00368 .00322 7.900 .00293 .00285 8.200 .00465 .00463 8.500 .00785 .00766
8.700 .00664 .00540 9.000 .00726 .00593 9.200 .00858 .00766 9.500 .00533 .00427
 9.80 .00377 .00311 10.00 .00359 .00299 10.59 .00272 .00228 11.00 .00212 .00175
11.50 .00191 .00162 12.50 .00177 .00157 13.00 .00180 .00164 14.00 .00182 .00170
15.00 .00382 .00375 16.40 .00246 .00235 17.20 .00264 .00249 18.50 .00221 .00212
20.00 .00251 .00242 22.50 .00252 .00245 25.00 .00250 .00246 30.00 .00276 .00274
 0.        0.        0.        10.
 1820.     20000.    5.
 6  7  1  0  1
  .20 .28600 .09530   .25 .28000 .05660   .31 .26200 .02060   .34 .24500 .01450
  .49 .18500 .01050   .51 .17600 .01000   .63 .14600 .00914   .69 .13400 .00914
  .86 .10800 .01020  1.06 .08910 .01080  1.54 .05790 .00924  2.00 .03510 .00348
 2.50 .02660 .00369  2.70 .02670 .00988  3.00 .02240 .00487  3.20 .02150 .00232
 3.39 .02090 .00222  3.50 .02100 .00171  3.75 .01950 .00143  4.00 .01820 .00154
 4.50 .01670 .00248  5.50 .01360 .00295  6.00 .01190 .00366  6.50 .01210 .00423
```

Table A2. Listing of Data for LOWTRAN 4 (Cont)

```
 7.20 .01330 .00629  7.90 .00784 .00504  8.20 .00809 .00702  8.50 .01530 .01160
 8.70 .02190 .01180  9.00 .02380 .01310  9.20 .02350 .01430  9.50 .01650 .00937
10.00 .01570 .00698 10.59 .01350 .00549 11.00 .01220 .00439 13.00 .00938 .00386
14.80 .00827 .00464 15.00 .01010 .00691 17.20 .01100 .00607 18.50 .00923 .00506
20.00 .01010 .00587 25.00 .00879 .00565 27.90 .00821 .00562 30.00 .00808 .00581
 0.         0.          0.          20.
 1820.      20000.      5.
```

Appendix B

Basic Flow Chart for LOWTRAN 4

A general flow chart for LOWTRAN 4 is given in Figure B1 which shows the overall mode of operation of the program. More detailed flow charts are also given for the main blocks in the program, that is, where the equivalent absorber amounts and refraction calculations are made (Figure B2), the transmittance/radiance loop (Figure B3), and the transmittance calculations (Figure B4).

The notation used in the flow charts is as follows:

(1) If a condition stated within a given block is fulfilled, then the direction of flow is sideways as indicated by the direction in which the block points (for example → for the following block ▭>).

(2) If the condition stated within a block is not fulfilled, the flow is downwards.

The numbers appearing on the flow charts correspond to the statement numbers given in the main program (see Table A1).

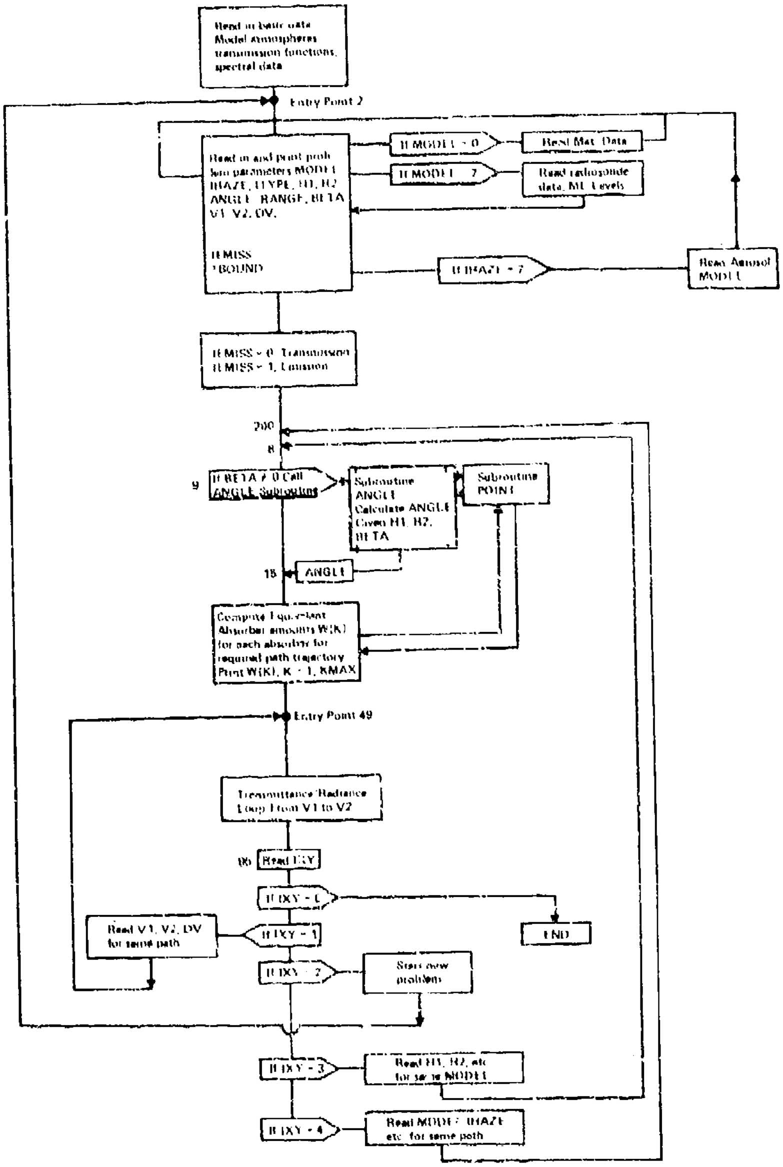

Figure B1. General Flow Chart for LOWTRAN 4

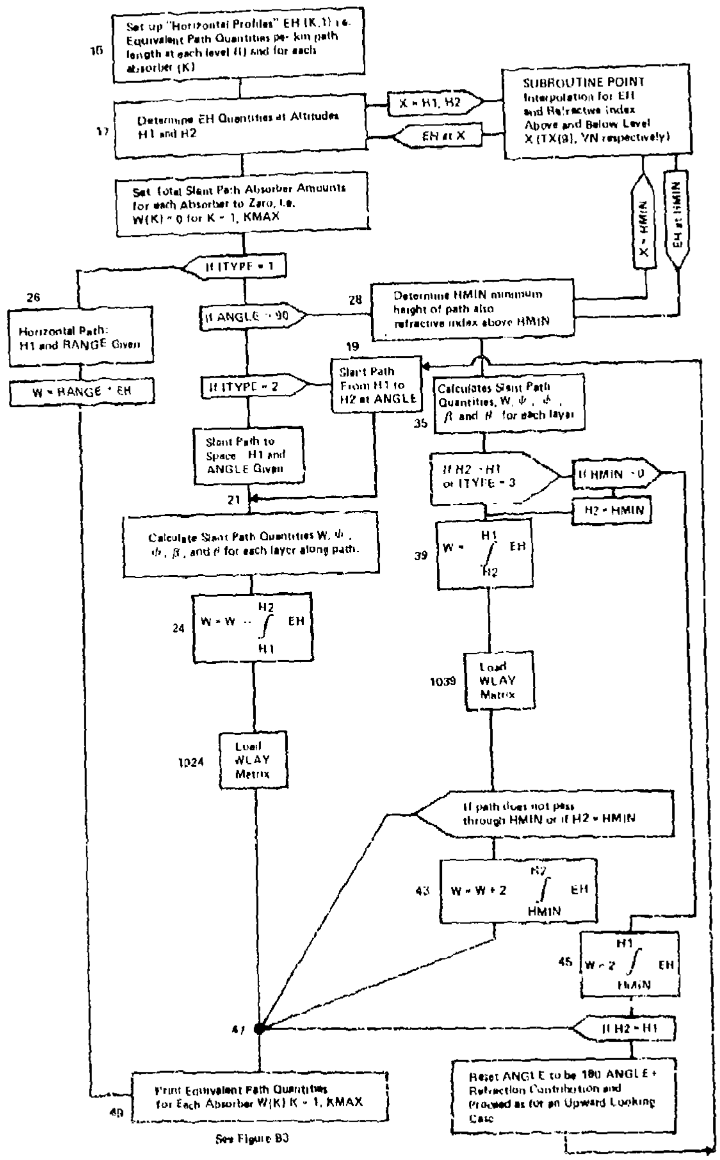

Figure B2. Flow Chart for Calculation of Equivalent Path Quantities

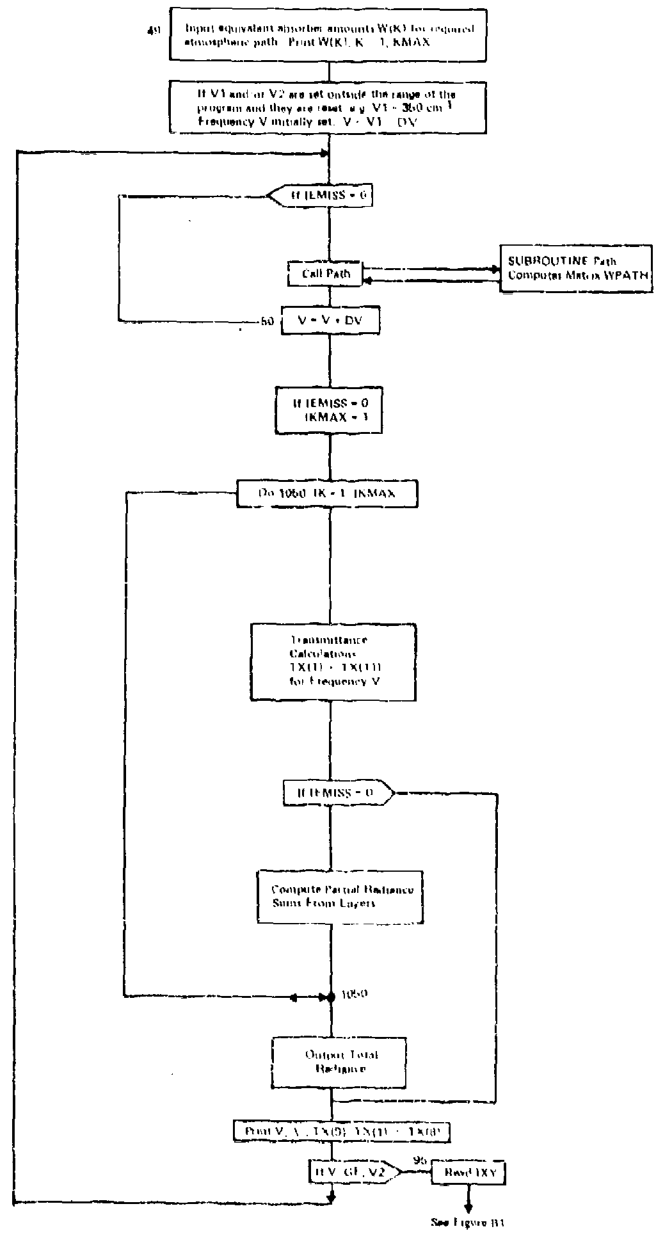

Figure B3. Flow Chart for Transmittance/Radiance Loop

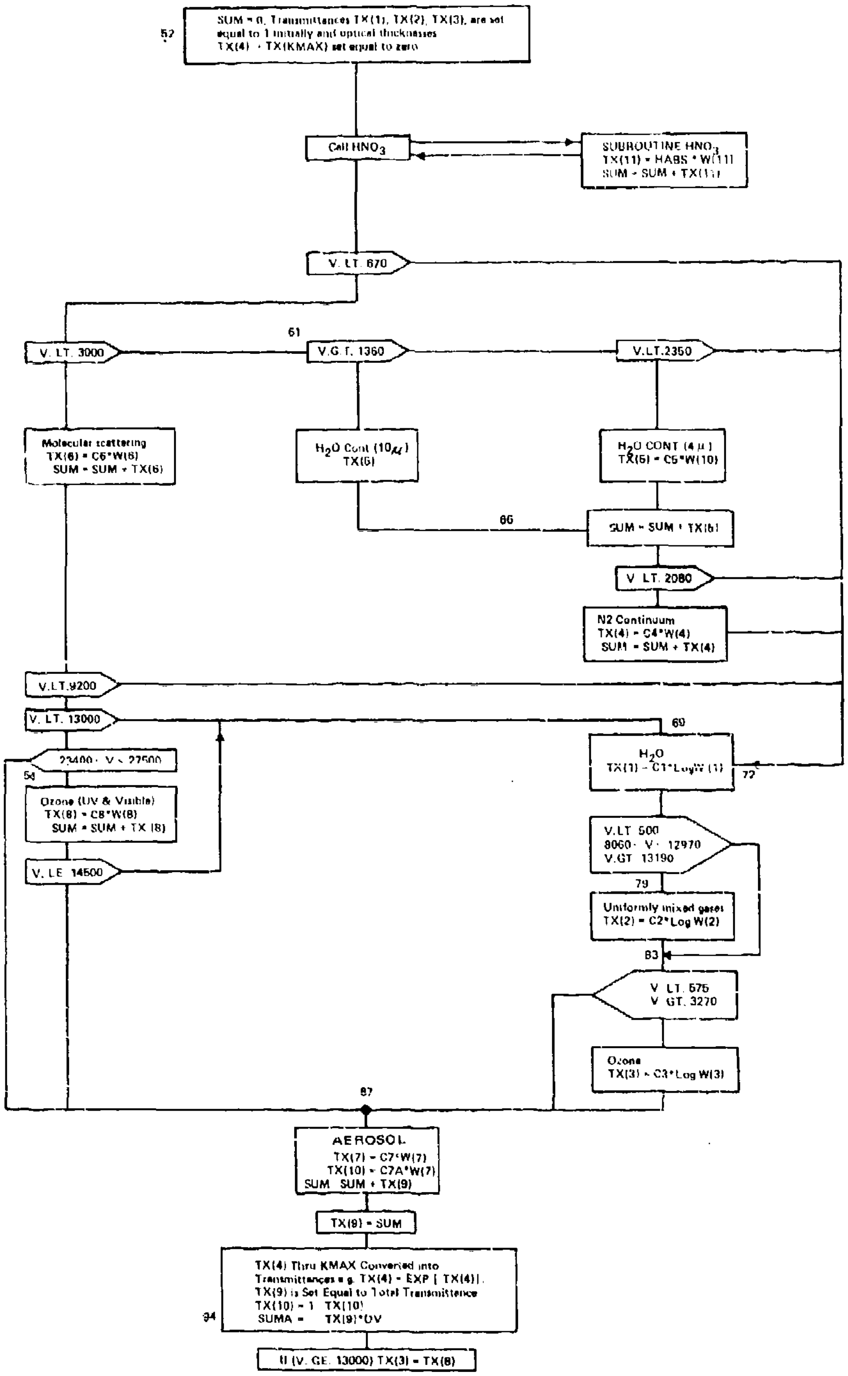

Figure B4. Flow Chart for Transmittance Calculations

Appendix C

Symbols and Definitions

AB	Absorption at frequency V; also average transmittance
AHAZE	Aerosol number density for MODEL = 7
AHZ2	Aerosol number density for MODEL = 7
AJ	Equivalent absorber amount per km at level J
ALAM	Wavelength (μm)
ALP	Angle of arrival at adjacent level
ANGLE	Input zenith angle (degrees)
AO	Constant $A = (R_o + H1)n_o \sin\theta_o$
AVW	Average wavelength used in refractive index expression
B	Storage parameter for BETA
BBG	Black body function of boundary times the total transmittance along the path
BBIK	Black body function of the IK layer and the frequency V
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended by path at earth's center
BJ	Equivalent absorber amount per km at level J + 1
CA	Conversion factor from degrees to radians
CO	Wavelength dependent coefficient used in refractive index expression
CW	Wavelength dependent coefficient used in refractive index expression
C1	Log absorption coefficient for water vapor
C2	Log absorption coefficient for uniformly mixed gases
C3	Log absorption coefficient for ozone

PRECEDING PAGE BLANK

C4	Absorption coefficient for nitrogen (~ 4 μm)
C5	Absorption coefficient for water vapor continuum (~ 10 μm)
C6	Extinction coefficient for molecular scattering
C7	Extinction coefficient for aerosol models
C7A	Aerosol absorption coefficient
C8	Absorption coefficient for ozone (UV and visible regions)
D	Water vapor amount (pr. cm/km) at level I
DTAU	Differential transmittance (due to absorption) across the IK layer
DP	Dew point temperature (°C)
DS	Path length from level I to level I + 1
DV	Wavenumber increment at which transmittance is calculated
DZ	Height increment from level I to level I + 1
E(K)	Equivalent absorber amounts per km at height H1
EH(1, I)	Equivalent absorber amount per km for H_2O at level Z(I)
EH(2, I)	Equivalent absorber amount per km for $CO_2 + N_2O$ etc at level Z(I)
EH(3, I)	Equivalent absorber amount per km for O_3 at level Z(I)
EH(4, I)	Equivalent absorber amount per km for N_2 at level Z(I)
EH(5, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (10 μm)
EH(6, I)	Equivalent absorber amount per km for molecular scattering at level Z(I)
EH(7, I)	Equivalent absorber amount per km for aerosol extinction at level Z(I)
EH(8, I)	Equivalent absorber amount per km for ozone (UV and visible) at level Z(I)
EH(9, I)	Mean refractive index of layer above level Z(I)
EH(10, I)	Equivalent absorber amount per km for H_2O continuum at level Z(I), (4 μm)
EH(11, I)	Equivalent absorber amount per km for nitric acid at level Z(I)
EV	Integrated absorber amount from level I to level I + 1
F	Function for determining saturation vapor density of water (gm m^{-3})
FF	Black body function (W/cm^2-ster-μm)
FAC	Interpolation parameter
FACTOR	Integration weighting parameter
FO	Transmission function logarithmic absorber amount scale for O_3
FW	Transmission function logarithmic absorber amount scale for H_2O and the uniformly mixed gases
H	Altitude dependent control parameter
H1	Initial altitude (km)
H2	Final altitude (km)
HABS	Nitric acid absorption coefficient

HAZE	Aerosol number density (no. cm^{-3})
HM	Estimated tangent height (km)
HMIN	Minimum altitude of path trajectory (km)
HMIX(I)	Nitric acid volume mixing ratio (times 1.0 E+09) at the level Z(I)
HSTOR(I)	Interpolated nitric acid volume mixing ratios
HZ(I)	Hollerith titles for visibili:
HZ1	Aerosol number density (no. cm^{-3}) for 23 km visual range
HZ2	Aerosol number density (no. cm^{-3}) for 5 km visual range
I	Running integer used as altitude (level) indicator and frequency indicator
IATM	Number of model atmospheres
ICOUNT	Output page counter
IDV	Frequency increment (cm^{-1})
IEMISS	Input control parameter determining mode of program execution (=0 for transmittance, =1 for radiance mode)
IFIND	Indicator for using subroutine ANGL
IHAZE	Aerosol model indicator
IJ	Equals IK
IK	Running integer used as layer indicator along the atmospheric path
IKLO	Lower limit of layer loop (=1)
IKMAX	Upper limit of layer loop
IL	Integer indicator used to determine if the atmospheric path intersects the earth
IM	Parameter used when reading in a new atmospheric model
IP	Indicator for using subroutine POINT to calculate refractive index only (IP = 0) or equivalent absorber amounts also (IP ≠ 0)
ITYPE	Indicator for type of atmospheric path
IV	Frequency at which transmittance is calculated
IV1	Starting frequency (equivalent to V1)
IV2	Last frequency (equivalent to V2)
IXY	Parameter for terminating program and cycling indicator
J	Running integer for altitude identification
JEXTRA	Integer indicator used when H1, H2, and HMIN are in the same layer (ITYPE=2)
JMIN	Altitude indicator for minimum height of path
JP	Print option parameter
JSTOR	Integer indicator used when vertical profile changes from downward to upward path
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
K	Absorber indicator, K = 1, 2, 3, etc., corresponds to H_2O uniformly mixed gases, O_3 etc, respectively

KMAX	Upper limit of absorber amount loops (= 11)
K1	Integer used in reading two model atmospheres on one card
K2	Integer used in reading two model atmospheres on one card and cycling parameter for downward looking paths
K4	Frequency indicator for nitrogen continuum transmittance calculation
L	Frequency indicator for ozone transmittance calculation
LEN	Parameter used for defining longest of two paths
LENSTOR	Integer storage for parameter LEN, needed for cases run in succession
L1	Frequency identifier for UV and visible ozone transmittance calculation
L2	Frequency identifier for UV and visible ozone transmittance calculation
M	Integer used to identify required model atmosphere
ML	Number of levels in radiosonde data input (MODEL = 7)
MODEL	Integer used to identify required model atmosphere
M1	Integer for selecting H_2O altitude profile for (M=M1)
M2	Integer for selecting temperature altitude profile for (M=M2)
M3	Integer for selecting O_3 altitude profile for (M=M3)
N	Indicator for level below given input altitude used in POINT subroutine; also as frequency indicator in UV and visible ozone transmittance calculation
NH	Frequency indicator for water vapor continuum transmittance calculation
NL	Number of levels in model atmosphere data
NLL	Equals NL-1
NP	Indicator for determining whether H1 or H2 coincide with levels in the model atmosphere
NP1	Value of NP for altitude H1
NP2	Value of NP for altitude H2
P(M, I)	Pressure (mb) at level I for model atmosphere M
PH	180° − PHI
PHI	Angle of arrival at H2
PI	3.141592654 that is (π)
PPW	Partial pressure of water vapor (in atmospheres)
PS	Total pressure in atmospheres
PSI	Angular deviation of path from initial direction
PT	Product of total pressure (atm) and the square root of 273/T(M, I)
RADMAX	Maximum value of radiance
RADMIN	Minimum value of radiance
RADSUM	Integrated radiance (W/cm^2-ster)
RANGE	Path length (km)
RE	Earth radius (km)

REF	Refractive index of air at level I
RH	Relative humidity (%)
RN	Ratio of refractive indices of air above and below a given level
RO	Earth radius (km) read in as input (=RE)
RX	Ratio of earth center distances between adjacent levels
R1	The product of the sine of the initial zenith angle and the earth center distance to starting altitude
SALP	Sine of angle of arrival at adjacent level (cf $\sin \alpha$)
SPHI	Sine of the local zenith angle at a given level (cf $\sin \theta$)
SR	Slant range (km)
SUM	Sum of the optical thicknesses of absorbers 4 through 11
SUMA	Accumulated integrated absorption
SUMV	Radiance (W/cm^2-ster-cm^{-1})
SUMVV	Radiance (W/cm^2-ster-μm)
T(M, I)	Temperature (°K) for model atmosphere M at level I
TAUG	Total transmittance to the boundary
TBBY(IK)	Average temperature of the IK layer
TBOUND	Input temperature of the boundary in °K
THET	Zenith angle at a given level (in radians)
THETA	Zenith angle at a given level (in degrees)
TMP	Ambient temperature (°C)
TR	Transmittance scales for transmission functions
TS	Ratio of standard temperature (273.0°K) to temperature at Level I
TSNEW	Transmittance (due to scattering) to the far boundary of the IK layer
TSOLD	Transmittance (due to scattering) to the near boundary of the IK layer
TS1	Ratio of 296°K to ambient temperature (°K)
TT	Ratio 273.15/(TMP + 273.15)
TX(K)	Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1, KMAX)
TX(9)	Total transmittance at frequency V
TX(10)	Absorption due to aerosol only at frequency V
TX1	Refractive index of layer above initial altitude H1
TX2	Refractive index of layer above final altitude H2
TX3	Refractive index of layer above minimum altitude HMIN
T1	Temperature of the boundary (°K)
T2	Temperature of the I+1 boundary used in index of refraction calculation
V	Running frequency (cm^{-1})
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VIS	Visual range (km) at sea level

VRMAX	Frequency of the maximum radiance (cm^{-1})
VRMIN	Frequency of the minimum radiance (cm^{-1})
VX	Wavelength at which aerosol coefficients are read in (μm)
V1	Initial frequency for transmittance calculation, cm^{-1}
V2	Final frequency for transmittance calculation, cm^{-1}
W(K)	Total equivalent absorber amount for entire path
WH(M, I)	Water vapor density for atmospheric model M at level I (gm m^{-3})
WLAY(I, K)	The absorber amount for the species, K, and the atmospheric layer, I
WO(M, I)	Ozone density for atmospheric model M at level I (gm m^{-3})
WPATH(IK, K)	The cumulative absorber amount of the species, K, for the IK layer along the atmospheric slant path
WS1	Transmission function scaling factor for H_2O at given wavelength
WS2	Transmission function scaling factor for CO_2, etc., at given wavelength
WS3	Transmission function scaling factor for O_3 at given wavelength
W2	Water vapor density for atmospheric model M at level I + 1 (gm m^{-3})
X	Input height to POINT subroutine
XD	Wavenumber interpolation parameter in UV ozone transmittance calculation
XH	Wavenumber interpolation parameters in H_2O continuum calculation
XI	Wavenumber interpolation parameter
XX	Wavenumber identification parameter for UV ozone transmittance calculation
X1	Earth center distance of level I
X2	Earth center distance of level I + 1
Y	Input zenith angle in radians
YN	Refractive index of layer below input height from POINT subroutine
YN1	Refractive index of layer below initial altitude H1
YN2	Refractive index of layer below final altitude H2
YY	Aerosol absorption coefficient at frequency V
Z(I)	Altitude at level I in km

Appendix D

Errata Sheet No. 2 (September 1977), Atmospheric Transmittance From 0.25 to 28.5 μm: Supplement LOWTRAN 3B(1976), AFGL-TR-0158, 1 November 1976, Environmental Research Papers, No. 587

1. Page 52 - Line A 3M should read A 3*
2. Page 53 - The second line A 81 should be removed
3. Page 54 - Reverse the order of statements A 103F and A 103G and relabel them:

   i.e., IF (M.EQ.0) Z(K) = H1   A* 103F
   J = IFIX (Z(K) + 1.0E-6) + 1   A* 103G
4. Page 56 - Line *A 185B should read:

   EH(5,I) = D*PPW*EXP (6.08*(TS1-1.0)) + 0.002*D(PS-PPW) *A 185B
5. Page 56 - Line A 204 is correct, i.e. IP=-1
6. Page 63 - Line A 586A should be removed.
7. Page 64 - Replace UALENTVENT by EQUIVALENT in line A 623
8. Page 78 - The 9th and 10th cards from the bottom of page 78 should be interchanged. The wavenumber identifications for these cards are 17800 and 19400 (see extreme right hand side of card).
9. Cautionary Note: When standard radiosonde data are used (MODEL-7 option), insert a card for sea level even though the required transmittance path does not extend to sea level. The reason for inserting the sea level altitude card is to correctly interpolate the aerosol number densities at the required altitudes for a given sea level visual range. However the above does not apply if the user is inserting his own aerosol extinction data for a given starting altitude.

10. Example: On page 79 a set of input data for LOWTRAN 3B is given. The first example (represented by the first three cards) is to calculate the transmittance for a 65° zenith angle slant path from altitudes 2.5 km to 8.5 km for a 23 km visual range (rural aerosol) subarctic winter atmosphere covering the wavenumber range from 2350 to 2450 cm^{-1} (i.e. 4.08 - 4.27 μm).

The four examples which follow are to calculate the average transmittance from 1820 to 20,000 cm^{-1} (i.e. from 0.5 to 5.5 μm) for a 10 km horizontal path at sea level (using the 1962 U.S. Standard Atmosphere) for four different aerosol models, namely, Maritime, Urban, Rural, and Tropospheric respectively.

It is recommended that the various aerosol model data sets be labelled and stored for further use.

The extinction coefficients for the Average Continental aerosol model originally contained in LOWTRAN 3 are included as an additional data set at the end of LOWTRAN 3B (1976) card deck available from the National Climatic Center, Federal Building, Asheville, No. Carolina 28801 for a charge of $20.00. (Please address requests to Mr. R. Davis.)

11. Page 25 - delete the last three lines on this page.

12. Page 26 - Delete lines *A 494 and *A 495, and change line *A 491 to read:

    NH = XI + 1.001

13. Page 33 - Lines A 85G and A 85H should be interchanged to be consistent with page 53.

14. Page 54 - Insert - IF(IXY.GT.3) GO TO 8 after A 104N.

15. Page 62 - A 563 should be

    IF(VIS.GT.0.0.AND.VIS.LT.2.0) XX=0.158

    Cautionary Note: The temporary fog correction will scale aerosol extinction regardless of atmospheric path. As presently coded, it probably should be restricted to horizontal paths (ITYPE=1) under 1 km in altitude.

16. Page 66 - Delete card C 21B in ANGL.†

---

†NEW ERRATUM

☆ U.S. GOVERNMENT PRINTING OFFICE: 1978--700-051--155